PLANS FOR EXPERIMENTAL AREAS AT THE NAL 200-400 BeV ACCELERATOR

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A. Introduction

The purpose of this paper is to assemble the secondary beams and dectectors proposed for NAL into the context of an overall experimental facility. To this end the operational efficiency and experimental flexibility must be considered as well as the physical and spacial requirements of the facility. Some of the secondary beams have been designed at this and previous summer studies and are contained in their proceedings.[1] It is hoped that a general purpose facility can be designed that will serve for most of the research objectives of the new accelerator. It is perhaps presumptuous to seek some "Master Plan" for experimental utilization; however, such a plan is desirable and useful. After further analysis by the NAL staff it can be used to generate cost estimates and engineering drawings. Finally, the resulting plan and layout can serve as a guide in the next round of beam design. At that time the experimental physicists will be asked to think of their beam designs and experiments in the context of such a layout of planned facilities. Hopefully, this will reaffirm the correctness of the plans or suggest changes in particular features.

B. General Features of the Experimental Areas

The experimental facility is served by a number of target stations. It is essential to have more than one station for several reasons. The most important might be called operational redundancy (or "don't put all your eggs in one basket"). The secondary beams orginating from a targeting station must be changed from time to time, leading to an interruption of the research program in that area. At such times the existence of other targeting stations means that the research program can continue. Furthermore, secondary beam equipment, located in a high radiation area near a target, often fails and the entire area must be shut off during "cool down". While repairs are undertaken or equipment changed, the research program can continue at other targeting stations. By these arguments it seems important to have at least three targeting stations. In this manner it is hoped that at least 2/3 of the research program can operate continuously.

A separate analysis of the magnitude of the experimental program needed at NAL[2] indicates that approximately 16 secondary beams are needed initially at the accelerator to satisfy the anticipated demand. Two to three targeting stations are needed to support these beams. The magnitude of experimental demand will grow in the subsequent years, and branches in secondary beams will be added to accommodate more experiments. At a later time, additional targeting stations may be added to increase the program capacity.

The target stations should be located with great care. Although the target areas may operate independently of one another, they should be positioned so that they provide sources of protons at several distances from at least one experimental area where immobile equipment such as the large bubble chambers are located. For example, low-energy beams into such an area require that the protons be targeted close to the detector while some high-energy beams may require the proton target position to be a kilometer or more away from the detector area.

Another major consideration in the placement of the target station arises from the expected increase in primary proton energy from 200 to 400 BeV. This will make higher energy beams possible and it will be expedient if such beams can be brought to the large detectors without their relocation. This is accomplished by constructing a new higher energy beam from a more distant target station. Thus, a progression of locations for the target stations with respect to the experimental area is desirable. This variety of possible target locations will produce flexible experimental areas.

It is not intended that too much attention be attached to the large detector area at this time. It is mentioned here because it helps to clarify the manner in which the target stations should be positioned.

It is suggested that the stations provide a progression of distances for the installation of secondary beams from the target stations to the large detector area. Otherwise, each target area will have many secondary beams and will be self-sufficient. It is assumed that protons can be supplied to each area simultaneously and with a variety of spills that are suitable for both electronic and bubble-chamber experiments.

Seven or eight secondary beams can be installed at each targeting station. The pattern of beams designed by H. White[3] consists of several neutral beams, two high-energy beams (150 BeV/c), two intermediate-energy beams (30-50 BeV/c), and two low-energy beams (~ 10 BeV/c) all from one target within the target station. It is suggested that the front ends of such secondary beams, the associated shielding, and the main muon filter be located within a building 100 feet wide by 400 feet long. Many of the secondary beams will emerge from the building and must be transported over long distances to the appropriate detector. It is assumed that the detector will be housed in a suitable enclosure and the secondary beam elements will be covered by relocatable buildings. In this manner, clustered about each target building, there will be an array of secondary beams leading to various detectors. It will be sugg sted in a later section of this report that, for at least one station, another permanent building be attached to the target building. In this way fewer temporary structures will be needed to house the initial round of experiments in that region.

In order to be specific about the location of one of the target stations, notice that the detectors are ~ 1000 feet downstream from the target in the beams designed by H. White.[3] Imagine that the detectors are enclosed in a building attached to or near the large detector area. Then the target area called "C" should be located approximately 1000 feet ahead of the area planned for large detectors (F). This is illustrated in Fig. 1.

The next target station should be farther upstream. The scale of distance is defined by an examination of the rf separated and neutrino beams. Both of these beams are to be used by the large bubble chambers that will be located near C. The rf-separated beam designed by J. Lach[4] has a length of 1000 meters for 100 GeV/c operation. This means that station B_1 should be ~ 3000 feet upstream from F. Around station B_1 will be a number of secondary beams of which one could be the 100 GeV/c separated beam. It is assumed that this beam will use superconducting cavities and, therefore, be suitable for use by both electronic and bubble-chamber experiments.

When the accelerator goes to 400 BeV, it will be feasible to build higher frequency cavities, but, even then, longer beam lengths will be required. It is estimated that a 2 kilometer length will be necessary for such a beam.[5] Since it is desirable not to move the large detector, the final target station "A" should be 2 kilometers upstream from the chamber. This places station A about 2500 feet ahead of station B.

The last general consideration concerns the creation of a ν beam for the large chambers. Following the ideas of L. Hyman,[6] the protons should target about 550 meters ahead of the chamber at 200 BeV. The pions produced in the target are focussed along a 450 meter decay path.

The pions and muons are then filtered out by 150 meters of iron while the neutrinos continue to the large chamber. Because of the special targeting conditions for neutrino beams and the heavy shielding required for the high intensities, it is suggested that a separate target area (B_2) be used. The protons could be targeted near the detector for low-energy neutrinos and farther from the detector for higher energy neutrinos. When the accelerator operates at 400 GeV, the target must be about 1 kilometer away from the chamber. In Fig. 1, the suggested proton beam comes from the splitting station SB. It is produced at about half the angle as the beam to station B_1 and is aimed directly at the chamber. The target station B_2 will be positioned along the proton beam according to the desired neutrino energy. Of course this proton beam could be used to create a muon beam or it could be brought very near the large detector area for hyperon beams or low-energy K beams.

C. Proton Beam Splitting

The previous considerations lead to the assignment of distances and angles shown in Fig. 1. These provide the appropriate space for the neutrino and rf-separated beams as well as allow for the eventual upgrading of beams when the accelerator goes from 200 to 400 BeV. In Fig. 1, the angles of splitoff for the branch proton beams are chosen to allow sufficient spacing between the experimental areas and the undeviated EPB line. The upper part of the EPB line is kept free for roads and utility distribution, although this is an area in which future targeting stations might some day be located.

As far as vertical distances are concerned, the protons emerge from the accelerator at an elevation of 728 feet, but the target stations A, B_1, and C are at ground level with the protons hitting a target at about 745 feet. This means that vertical bends of ~ 1° must be given to the protons on each branch following their split from main proton line. The protons rise 17 feet during about 1500 feet of longitudinal distance and must be bent again so that they strike the target horizontally.

The ν-beam target station, B_2, obtains its protons from the SB-split rather than an additional splitting station in order to save magnets. One simply uses half of the magnets at the SB-split that are already being used for deflection to station B_1. Approximately 14 magnets (each 20 feet long and operated at 10 kilogauss) are used for the 7° deflection to B_2, therefore, there must be sufficient spacing between two groups of 7 magnets to accommodate one or more additional magnets that provide the deviation out of the B_1 channel into the B_2 channel. These additional magnets are probably septum-fast-pulsed magnets that provide maximum compatibility between each branch. An alternate scheme that should be investigated, however, is the possibility of using a small scatterer to provide low intensity, long-spill protons for tuneup at B_2 while B_1 is in operation. This might avoid the septum magnets. If one dictates that during high intensity operation at B_2, that B_2 will not be compatible with B_1 (it of course will still be compatible with A and C), then even the fast pulse magnet can be eliminated.

The B_2 station is seen as a generally incompatible station, perhaps underground, that is designed with particular care for the ν-beam and maximum shielding for the bubble chamber. Any other simultaneous-spill experiments might create background to the chamber. However, this depends on details of the ν-beam and the final muon shielding for the chamber.

The distance SB to F in Fig. 1, is ~ 5000 feet. Thus, the length of the ν beam (B_2 to F) can be chosen as any distance up to about 4000 feet which should be adequate at 400 BeV.[7]

Another general question for consideration, recognizing the dual use of magnets at switching station SB, is whether to leave space between the horizontal deflection magnets at SA and SC for the possibility of other special target stations (similar to B_2) in the future. For example, it may be necessary to obtain a neutrino beam length of ~ 7000 from an additional split from switch station SA rather than SB if higher energy neutrinos are required.

D. The Basic Thick Target Station

It is believed that each target station will be somewhat different in design, thus, the word "basic" is misleading. The nature of the differences is described in the next three sections. Here a few general features are mentioned and illustrated by Fig. 2.

In Fig. 2, S is a shielding enclosure which is modular or earth covered or some combination thereof. This shielding encloses the target, the beam dump, and some of the initial elements of a number of secondary beams. M is the muon shielding which is a combination of uranium, iron, and concrete modules approximately 200 feet long. The modular nature of this shielding is required because it contains a large number of secondary beam elements. This shielding complex is surrounded by a basic building with a heavy duty crane that is used to manipulate the shielding modules as well as service the high density of secondary beam elements in this area. The building size of 100 feet $\times$ 400 feet is thought to be a minimum size. Aside from the large amount of shielding, space to unstack the shielding, and secondary beam elements, there is also a large number of power supplies, vacuum pumps, control racks, and possibly several experimental setups that utilize short low-energy beams.

The building crane might be constructed for 100-to-200 ton capacity loads in order to stack or unstack a given weight of shielding at a faster rate. Note that the building and crane may or may not cover the area S depending on the type of shielding that is used. We will try to be more specific as we discuss each experimental area in the following sections.

E. The A Target Station

The purpose of the A station as envisioned here is that it should be geared for operation at machine turn-on with the first round of experiments. As the protons for the station A target are deviated by the first splitting station, it will have initially some priority over the other stations. It would be difficult to work on the SA-splitting station without turning off the whole machine program. On the other hand, it should be possible to continue to work on subsequent stations with suitable safety precautions (perhaps an extra beam dump might be used upstream).

The first round of experiments at Station A might be somewhat conventional and accommodate a degree of immediate success and experience. This would provide an early guide for future expansion of the facilities. For this purpose one should try to design this area with maximum flexibility. Stations B and C, while providing general purpose beams, are tied to some extent to the large bubble-chamber facilities and consequently may not initially offer the full flexibility and utility to general counter and/or spark-chamber experiments that Station A could provide.

Figure 3 shows the general plan for the A Station. The fundamental elements of the plan are the following:

(1) thin target station (call it A')

(2) thick target station (A)

(3) basic experimental area (E)

(1) <u>The thin target station.</u> The thin target station (where about 1% of the protons interact) essentially takes the place of the now absent internal target area. It provides nearly all the features of the internal area (along with additional advantages) except for multiple-traversal efficiency in targeting and the ability to operate without the external beam.

The consolidation of the thin target area A' with the thick target area A provides some cost saving in the A' area when compared with an isolated thin target station. On the other hand, the proximity of the A' station causes additional expense and modification to the A area if the A station were to utilize earth shielding. If one assumes, however, that A station has flexible, modular shielding, then there is probably not much additional cost to the A station because of the addition of A'.

The potential savings for the thin target station A' caused by the consolidation with the thick target station A are

(a) the additional EPB tunnel and/or transport that would be used between A and A' if they were separated by a large distance

(b) the additional utility distribution system for a separate experimental area

(c) additional muon shielding

(d) additional building structure

The need for a thin target station might be summarized as follows:

(a) A' is needed for special experiments that can most conveniently be done there such as:

(1) large angle p-p elastic and inelastic p-p scattering

(2) particle production studies at near 0° by studying laboratory production near 180° in the laboratory.[8]

(3) experiments that require the target material to be varied.

(b) A' can provide a number of relatively low intensity (~ 5-30 GeV/c) secondary beams for experiments.

(c) A' can provide a cheap system of beams that might be used for test purposes.

In addition to "potential saving" there is another category of items which might be classed as advantages of a thin target station.

(a) There is no beam dump or specific muon shielding. The muon shield of the A station downstream is utilized. Of course, this can become somewhat complicated depending on the exact distance between A' and A, and also on the manner in which secondary beam magnets are placed with respect to the thin target.

(b) The basic shielding for the thin target station is modest relative to that of the thick target station. Exact details will have to be studied; however, the shielding wall is probably no more than 10 feet of heavy concrete with perhaps a minor amount of Fe or U immediately surrounding the target. This reduced shielding means that a beam line can probably be changed within a day or two.

(c) The target area is relatively cool with regard to radiation problems and is not appreciably different than existing target stations at smaller accelerators. Nearly all of the beam energy is carried downstream to the A target station. Thus the area is accessible and the fact changes noted in (b) above seem possible.

A few of the potential problems created by the thin target station are listed below.

(a) The thin target station of course is not accessible during operation of the thick target station. The relative priority of A over A' should be recognized unless physics considerations determine otherwise.

(b) Special considerations for handling the target and beam dump at the downstream station A will have to be studied.

(2) The A Thick Target Station. This is a version of the "basic" thick target area described in Section D. In this particular station it appears that modular shielding will be required around the target and beam dump. Some additional thoughts or details of these items are given in the appendix. The important point is that this target station should be designed with maximum flexibility.

(3) The Basic Experimental Area (E). The size of this building (~ 200 feet wide × 400 feet long) with bridge crane is determined by extrapolation from present day experience at other accelerators and by the consideration of a preliminary beam layout by H. White.[3]

The basic reasoning is that this area covers a high density of see-ondary beams as well as experimental setups. It they were located outdoors, they would probably not be accessible to portable cranes--indeed even a fork lift might not be able to get through to them. It is believed that the time saved by being able to properly service this area by an overhead crane (assuming an operations cost of $1 M/week) will easily pay for the cost of this structure in a relatively short time. (We are aware that this is an overall saving and is not directly traded between "operations" and "construction".)

This experimental area is considered a minimal area. It is about the same size as external beam experimental areas used at BNL, ANL, and LRL. At 200 BeV some of the highest energy beams will extend beyond the limits of this building. At this point the density of beams and experiments should be somewhat lower such that techniques with portable cranes and relocatable experimental housing can be used.

One possible method for taking care of this situation is shown in Fig. 4. A narrow conrete pad is poured along the beam line and a somewhat larger pad at the end of the system for the experimental area. It is assumed that utility distribution points are available around the perimeter of the experimental building (either underground or above beam height). Thus 480 volt power, water, controls, communications, etc. would be piped along the concrete pad to power supplies for beam elements as well as to the experimental area. This distribution system (bus bars and water pipes) should be designed as a portable quick disconnect system. Whenever necessary, a small relocatable enclosure is dropped over the magnet and power supply. A somewhat larger relocatable building might be used for the experimental building at the end of the beam line. This, of course, will be determined by the specific experiment. In certain cases, special temporary buildings may have to be constructed for the experiment.

(4) Summary of Station A Complex. This station consists of a thin target area (A') and a thick target area (A). Modular shielding surrounds both target areas for maximum flexibility. While the thick target station alone would call for a building ~ 400 feet long × 100 feet wide, the addition of the thin target station would perhaps determine an overall building covering both target areas that is 500-600 feet long × 100 feet wide. The experimental-area building (200 feet × ~ 400 feet) follows the target area buildings and is expected to enclose a large fraction of beam lines and experiments. Portable enclosures and handling methods will be used for those experiments extending beyond the permanent buildings.

F. The B Target Station

The B Station is a basic thick target station as already outlined in Section D. It is intended that station B be a full scale facility. Initially, a large experimental building similar to the one recommended for target Station A would not be included. This is not because it is not needed, but rather to wait until experience is gained at target station A and then perhaps add an experimental building as soon as possible that will be an improved version of the Station A building. For the above reasons the initial density of beams and experiments at Station B is not expected to be as high as the density at Station A.

One of the principal beams intended for installation at the B station is the 100-BeV rf-separated beam that will serve the bubble chamber (s), streamer chambers or any similar detectors. However, the experimental area for this beam is necessarily ~ 1 kilometer removed from the B station and so does not make any strong demands on the B experimental-area building. While the rf beam is only one beam, it is a rather stable beam and so imposes some limitation on the maximum flexibility of the B station.

A final recommendation for the B station experimental area is to pour a concrete pad approximately the size of the A station experimental building (~ 200 feet × 400 feet) with appropriate allowances for the utility distribution system.

G. The C Target Station

The C Station facility should be designed initially in exactly the same manner as the B Station, that is, it is a basic thick target station. However, we wish to point out certain aspects which make the specifications for the C Station a little uncertain.

The C Station will be closely tied to the large facilities (bubble chambers, streamer chambers, etc.) which are not mobile. Thus, the distance from the C target to these facilities is not known precisely because actual beams have not been specified. The only two specific beams, the ν beam and the rf-separated beam, come from the B_2 and B_1 stations respectively. Although this fixes the positions of the large chambers, the position of the C target is an adjustable parameter within certain limits.

Some preliminary considerations are as follows: A distance of 1000 feet can be chosen as between the C target and the large facilities. This allows a reasonable spectrum of secondary beams to reach the bubble chambers, etc. as well as to be directed to other experiments. The C station might first be used as a thin target station with modular shielding. This design is drastically different from that of the thin target station at A' because it involves the complete muon shield as well as a beam dump. This particular facility is not significantly cheaper than a thick target area nor is it intended to be.

With the above consideration, three choices are available depending on the development or need for hyperon beams or other specialized beams to the large detector area.

(1) C could be expanded into a thick target area at the same place (~ 1000 feet from the detector area).

(2) The initial thin target area at C could become a thin target area like A' with the development of an additional thick target area downstream closer to the detector area. The choice of hyperon beams might determine this.

(3) The C Station could simply be moved downstream closer to the facilities as either a thick or thin target area.

None of these choices violate the initial statement made in the first paragraph, i.e., the C Station must be considered for planning purposes to be a basic thick target station and the design and cost should be similar to that described for the B Station.

H. Large Detector Area

As described earlier, space has been provided for locating large detectors such as bubble chambers, or superconducting spectrometer magnets at the end of the ν-and rf-separated beams. This area will also be served by beams originating from targeting station C. It will be appropriate to enclose part of this area in a building but the details about how this should be done will have to await the final definition of Station C.

The 25-foot bubble chamber sits outside a building as it is presently envisioned. It will be served by both the neutrino and rf-separated beams. It is planned that the rf beam be able to be switched into another nearby location and be used for counter experiments when the chamber is unavailable. It is suggested that these counter experiments be located in a nearby and perhaps adjacent building. The building and the bubble-chamber area might share the same crane as illustrated in Fig. 5. The building can be easily expanded towards the C area when beams are available from that region.

There are other factors which contribute to the uncertainty of the large detector area as well as target station C. At this point there are unknown safety requirements for the large chamber(s). For example, what degree of isolation will be required and how much associated equipment for the chambers must be nearby? In addition, further study of the neutrino beam(s) and associated backgrounds in the chambers might require the chamber to be buried underground. There is also additional controversy over the usefulness of the large chamber for strong-interaction physics which must be resolved.

I. Epilogue

We have attempted to develop ideas about the experimental areas that can accommodate a wide variety of experimental situations. We have substantially increased the possible number of secondary beam setups over what was included in the Design Report and made use of more external target stations. Furthermore, we have suggested that a greater amount of enclosed experimental area be provided so that a larger number of experimental setups can initially be contained within permanent buildings. We have also defined certain major secondary beams and recognized the need for an experimental area for large detectors.

These ideas and the related plans are meant to establish a goal for the development of the experimental areas. We have not had the time nor assistance to make a cost analysis of these plans. It may be that certain features of the plan will need to be modified to stay within the prescribed budgets.

It is now appropriate to publish this paper and invite comments. Undoubtedly, by the time of the next Summer Study, additional ideas will exist, and this plan will have to modified.

J. Acknowledgments

This is a report of Section D1 in the 1968 Summer Study. In addition to our work, many discussions were held with E. Goldwasser, A. L. Read, and A. Maschke. The ideas of these people and of many others are folded into this paper. However, the choice of words and the errors are due only to the authors.

APPENDIX A

An Alternate General Layout

We cannot take this plan too seriously at present because of some intuitive feelings and insufficient time to consider all aspects. The chief merit of this plan is an apparent saving of ~ $4M. Figure 6 is a sketch of the alternate system. It is not drawn to scale so consider the distances the same as in the plan view of Fig. 1.

The general difference of this plan compared to the one in the report is that only one straight trench perhaps no wider than 4 feet at any point is dug for the entire EPB system. The upward branches, SA-A, SB-B, SC-C, all fall within this same trench which is, of course, eventually a tunnel in places. The precise depth of this tunnel with respect to the target stations would have to be studied in more detail.

The possible savings (not necessarily advantages) are as follows:

(1) The three extra tunnels (see Fig. 1) from the 7° horizontal splits are eliminated. This is a total of nearly 5000 feet which is $1M.

(2) The 42 magnets (14 for each 7° horizontal deviation) along with their power supplies, utilities, controls, interlocks, etc. are eliminated. This is ~ \$ 1.5M.*

(3) The tunnel enlargements for splitting stations (SA, SB, SC) in Fig. 1 which might be up to 25 feet wide near the final magnet are eliminated. Considering 3 such areas, there is possibly \$ 0.5M to be gained.

(4) Some of the major transverse power and utility distribution system is eliminated. All major power utilization (the EPB as well as the experimental areas) are all along the same straight line. ~ \$ 0.5M.

A rather unique feature of this layout is the choice at any later time (assuming the EPB can be brought through a target station) of sharing beam between the 3 stations (A, B, and C) via the septum magnet at splitting stations SA, SB, and SC <u>or</u> series targeting all three stations A, B, and C with one beam dump at the end.

The following are some potential problems along with a somewhat crude analysis.

(1) In the original plan, the main access road together with shops, etc. were along the left side of the EPB line separated from the target areas by 200 ft. It is not obvious that this same

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*This is capital cost plus installation. There is probably a significant additional gain in operational time over the years whenever 42 magnets are eliminated from a system.

plan of road and buildings cannot simply be displaced transverse to the EPB line by about ~ 300 feet and still have exactly the same relationship and function as originally intended.

(2) Heavy target station shielding on top of the main EPB line. For this problem, consider the following possibility in construction. (Fig. 7)

In cross sections j and l, the small square buried in the ground is, for example, a 2 ft $\times$ 2 ft preformed concrete box in which the beam vacuum pipe is suspended with suitable holders for alignment. A man could travel through the box on a rolling cart below the vacuum pipe.

The essential point is that the small box should be able to take the load of the shielding. In all probability, caissons may be required anyway such that much of the load will already be taken to a level below the box. Details of the EPB optics have not been considered here and, of course, may change some of these considerations.

(3) Interference between target stations. If the target stations are placed ~ 2500 feet apart, as in the original report, even the highest energy beams will easily miss the subsequent station with only a fraction of the bending magnets that they would normally use.

(4) The ν beam has to some extent been ignored here. It might require a special splitting system (several degrees horizontally) or either utilize station B itself. This is, of course, contrary

to some of the arguments that we used in the preceding master plan.

(5) As far as shielding problems are concerned, it is assumed that each target station must be sufficiently shielded for the experiments and personnel in the immediate area. Thus it does not seem likely that one target station can create additional background problems to a subsequent target station. The beam splitting stations have over 1000 feet of earth between them and the experimental areas and in principle should not be troublesome. The special case of the shielding for the ν beam is not a problem because its time of targeting is different from that of other spills.

APPENDIX B

Some Details of a Thick Target Station

In Section D of the preceding paper, the overall features of a thick target station were outlined without detail. If we refer to Fig. 2, the area noted as S contained the target, beam dump, collimators, and the initial magnets of many of the secondary beams. The core area containing these elements must be surrounded by an appropriate amount of shielding. There are many technical problems associated with the core area because it is highly active, hence special remote handling techniques must be used.

Maschke[9] has proposed one method of dealing with the problems, that is, by withdrawing the core elements which are all enclosed in a long box via a railroad track system to another site. While this part of the proposal, or some modification thereof, will almost certainly have to be used, the additional suggestion of one immobile concrete and earth tomb surrounding the area seems objectionable in many cases. This is not important if one assumes that a new station can always be built further down stream beyond this movement at a later date; however, this is not a real saving.

In the preceding paper, a thin target area (A') has been suggested for the A Station and the uncertainty of the C Station (see Section G) demands that it be somewhat flexible. This leaves only stations B_1 and B_2 as possibilities for fixed shielding. We suggest this might be further limited to B_2 which is thought to be at this time a rather inflexible "fixed" target station specifically designed for the production of the ν beam.

The other extreme alternative is to use complete modular shielding over the core area. This may amount to ~ 25 feet of heavy concrete or a lesser thickness if some combination of uranium, iron, and concrete is used. This method will cost considerably more initially, however, it will probably be considerably cheaper in the long term by providing the flexibility for changes. These changes will be determined by the physics of interest 5 to 10 years from now and it is impossible to determine what they will be at this date.

One possible version of the Maschke Box might contain the target and its control mechanisms, the beam dump along with its cooling system, a number of magnets together with their power, water and interlock cables, etc., and perhaps also hundreds of tons of shielding. It is difficult to think of moving this whole mess because of the failure of one item, no matter how trivial.

There is no doubt that there will be many problems in the core area as experienced at other accelerators. As an example, we refer to the note of M. Perl[10] which states that in the first two years of operation at SLAC, "a great deal of work must be done on the parts of the beam transport systems near the target or on the targets themselves. The reasons for this work are experimental design errors, failures of new instrumentation such as monitors and interlocks, damage to apparatus from high power, surveying errors and the need to periodically check the area." This observation applies equally well to other operational accelerators.

One suggestion that may prove advantageous in dealing with the ideas of the last two paragraphs is to compartmentalize the core area, or if you wish, segment the Maschke Box. If there is trouble with the target, then remove or replace only the target. This idea calls for some kind of railroad track in a small tunnel below the core area on to which the appropriate item (in particular the target and the beam dump) can be lowered and then extracted. While it is not feasible to go into engineering details at this time, the general rule we are suggesting is "do not disturb equipment that is operating properly otherwise the problems may cascade."

The idea of compartments in the core must be utilized for the modular shielding scheme. If it is necessary to dig through the shielding, this can be done fairly rapidly for a specific item. When servicing or replacing a magnet, life would be easier if the target and dump were removed. In any case, special handling techniques must be used and they will not be significantly different in principle whether performed in place or in another location.

Some of the reasons behind the push for flexibility are as follows: The general beam layout of H. White[3] which we have used as a guide is only one possibility. There are numerous ways of distributing secondary beams, some of which have been listed by A. L. Read.[11] Each method has certain advantages and disadvantages, but the area should be capable of accommodating many of the possible ways. As an example consider the 5 mrad beam of H. White. The first quadrupole is nearly 100 feet from the target and displaced only 6 in. from the EPB line at this point. In this 30 BeV/c beam, a single deflecting magnet 5 feet long and operating at 20 kilogauss, if placed immediately behind the production target would displace this beam 6 in. away from the EPB center line in a distance of 16 feet. This provides a potential gain of a factor of 36 in solid angle. While such a scheme creates other problems in compatibility or increased muon shielding, it can deflect low energy beams almost entirely out of the muon shielding, provide either larger solid angles or smaller production angles, or allow larger magnets i.e. thicker septums etc., to be used in the beam lines.

From the seminar by Drell this summer there was a preliminary indication that maximum intensity (maximum solid angle) for secondary beams may be important for the study of two-body strong interactions at large s and t. Other discussions have singled out the possible uses for high intensity ($\sim 10^9$) and high momentum resolution muon beams. (See details of the beam of Yamanouchi.[12])

Hyperon beams may create extraordinary demands. For example, it may be necessary to place superconducting magnets as close to the target as possible.

There may be a need to have a system of magnets to deflect the proton beam out of the shielding to a subsequent target station downstream.

For any given configuration of beams, the shielding may be found to be inadequate and may require a complete redesign with the addition of more uranium or iron closely packed about the target and beam dump or along a particular secondary beam channel.

There may be a need to split the beam among a number of targets in the same area, a circumstance that might also call for drastic shielding rearrangement.

Some of these considerations are major tasks which are assumed to be somewhat infrequent and some are minor. The point is that they can be done if the physics demand requires them without asking for a completely new target station and experimental area. It would be tragic to spend the enormous effort in time and money for the design of the world's largest accelerator only to find it crippled by inflexibility at some time in the future.

Figure 8 is a schematic possibility for a target area. The 3, 6, and 10 mrad beams might be considered essentially the same as the 2.5, 5, and 9.5 mrad beams in the H. White[3] design. The items labeled T, P, and D might be considered together as a segmented mini-Maschke Box with transverse dimensions ~ 8 in. T is the target box and is removable from either the front or from below. D is the beam dump and is removable by going directly upstream or it might be lowered first and then proceed upstream through a hole below. P, for all practical purposes, is an empty pipe ~ 40 feet long $\times$ 8 in. wide $\times$ 2 in. high. With appropriately thin side walls, it may be unnecessary to couple this vacuum system to those of the secondary beams in most cases. Detailed design of the beam dump may change some of these considerations.

REFERENCES

[1]UCRL-16830, Vol. I, 1964-65.

UCRL-16830, Vol. II, 1964-65.

UCRL-16830, Vol. III, 1966.

NAL Summer Study Reports, 1967.

NAL Summer Study Reports, 1968.

[2]Private communication with L. Jones, A. Krisch, W. A. Wenzel, and A. L. Read.

J. R. Sanford, NAL Summer Study Report D. 1-68-52, 1968.

[3]H. White, NAL Summer Study Report B. 7-68-16.

[4]J. Lach, UCRL-16830, Vol. I, p. 190.

[5]J. Lach, NAL Summer Study Report B. 3-68-43, 1968.

[6]L. Hyman, NAL Summer Study Report B. 1-68-20, 1968.

[7]L. Stevenson (private communication).

[8]D. O. Jovanovic, UCRL-16830, Vol. III, 1966, p. 11.

[9]A. Maschke, NAL Summer Study Report B. 7-68-39, 1968.

[10]M. Perl, NAL Summer Study Report B. 7-68-46 (not included in published volumes), 1968.

[11]A. L. Read, UCRL-16830, Vol. III.

[12]T. Yamanouchi, NAL Summer Study Report B. 2-68-38, 1968.

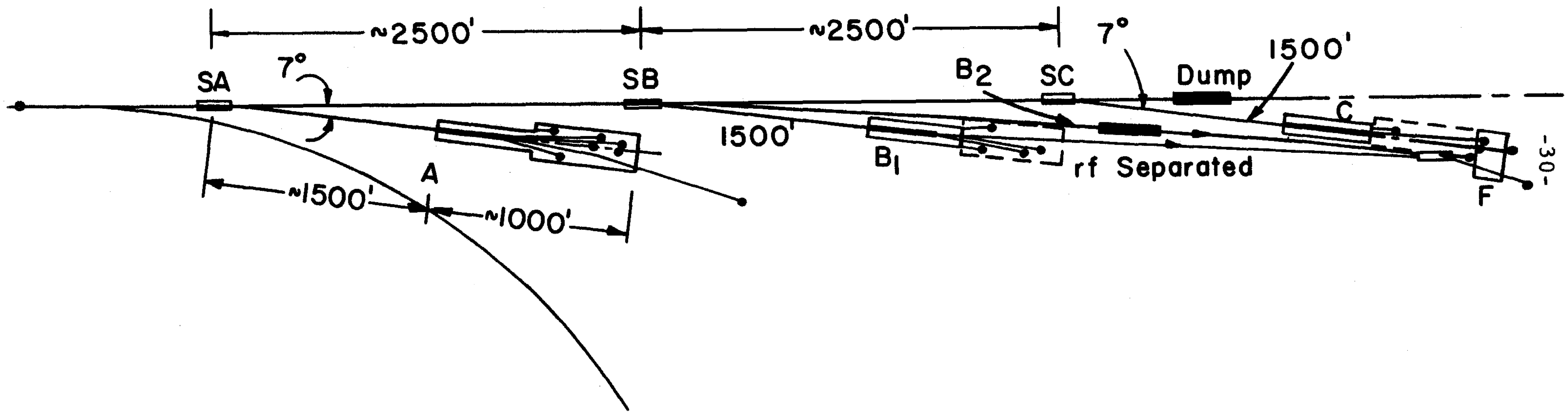


Fig. 1. Experimental-area layout showing location of target station C.

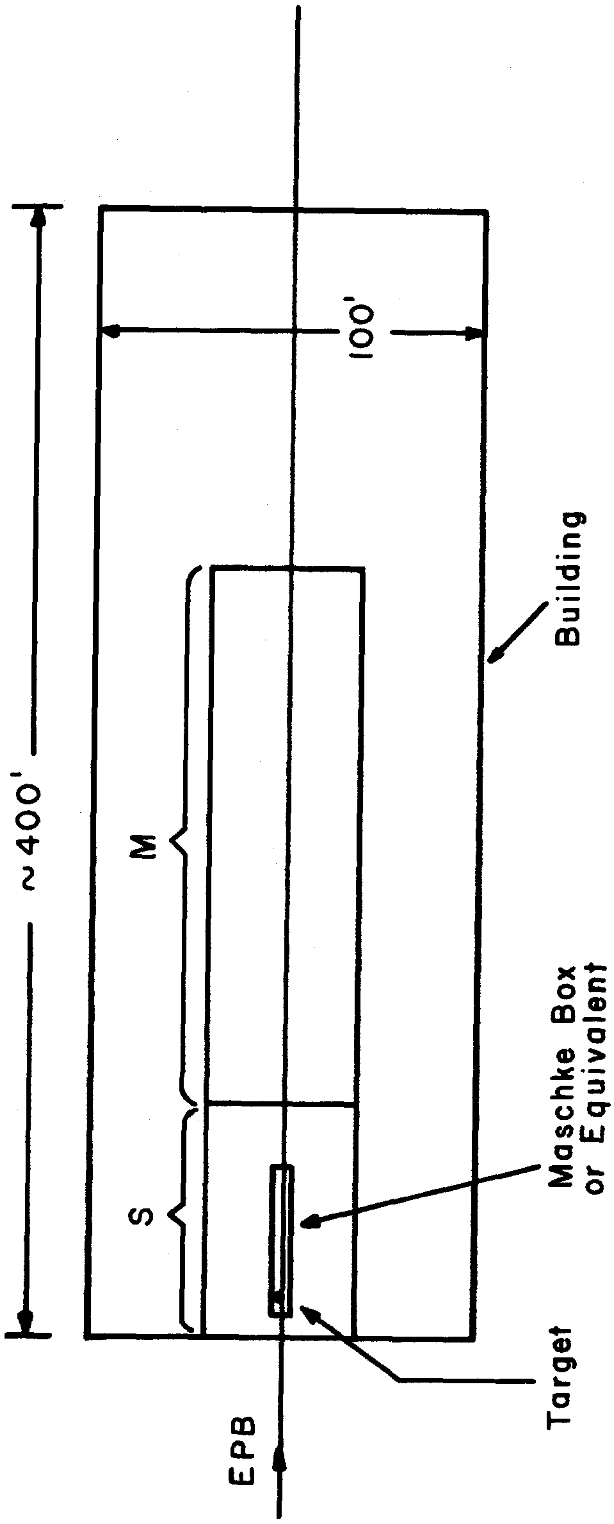


Fig. 2. Design of a thick target station.

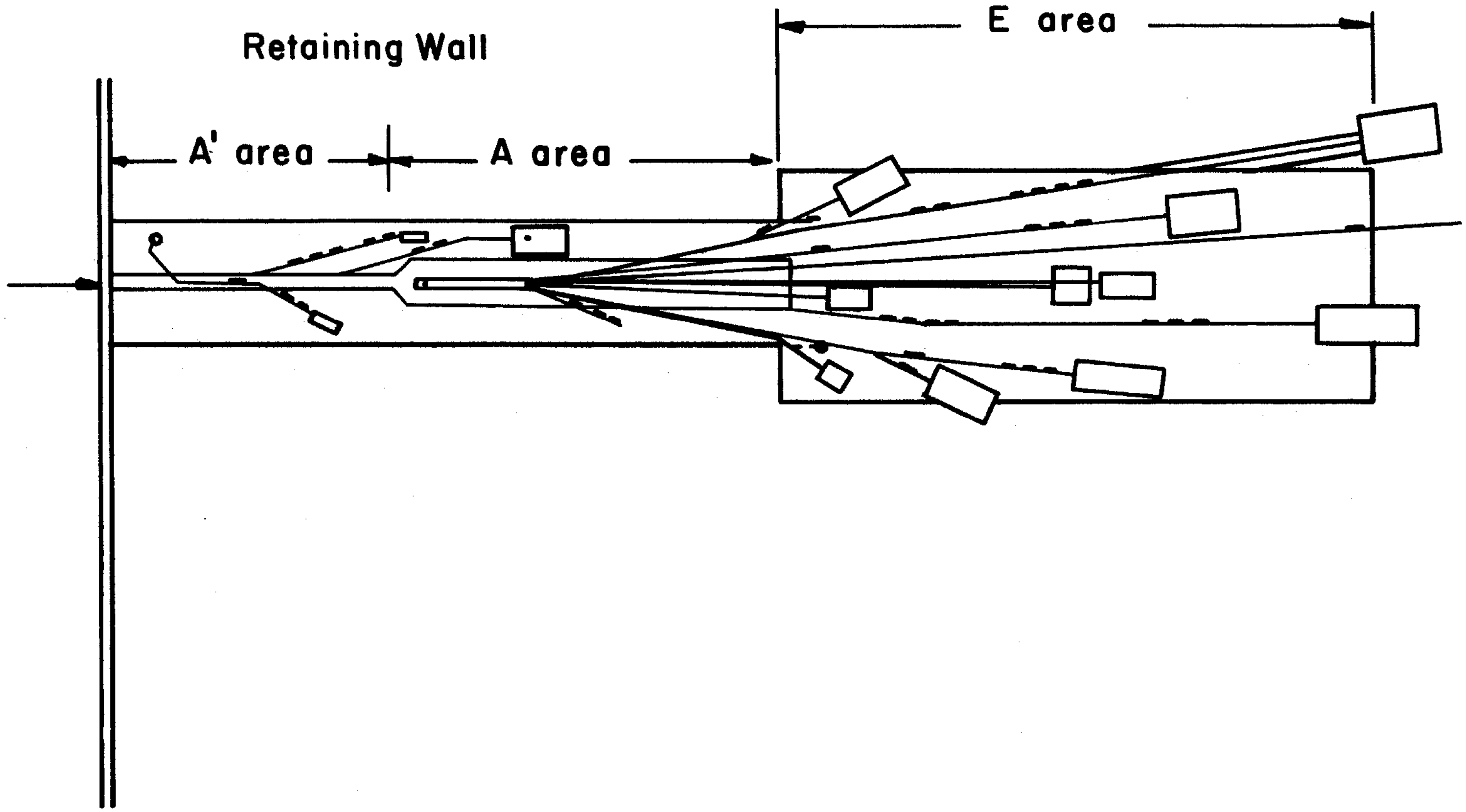
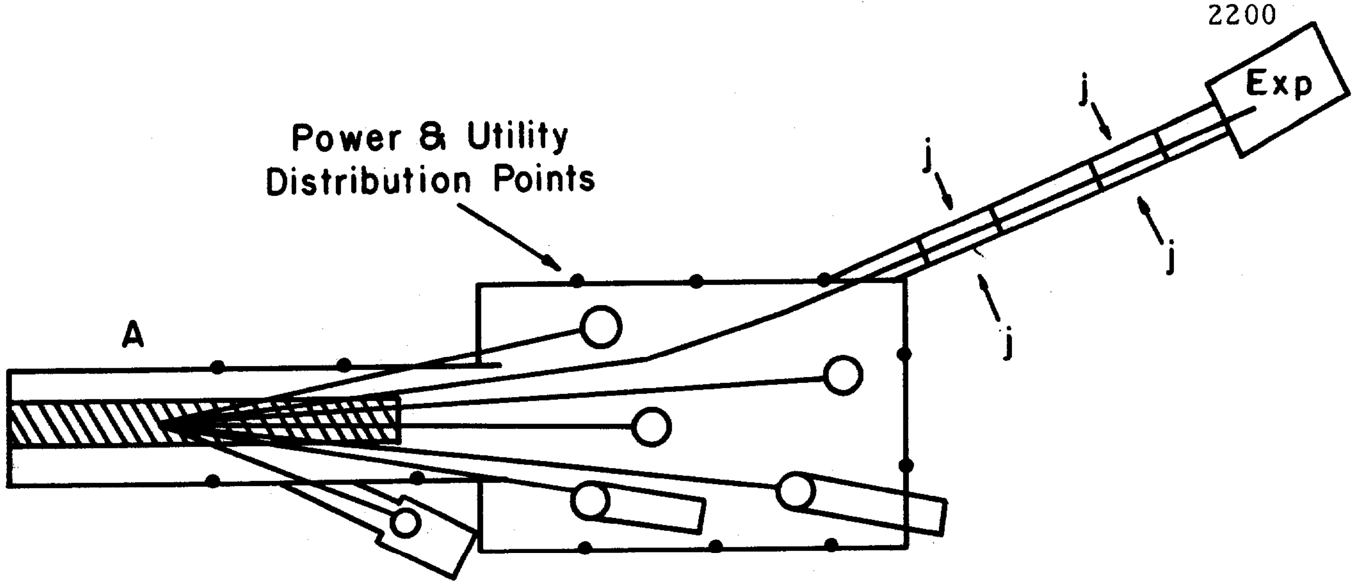
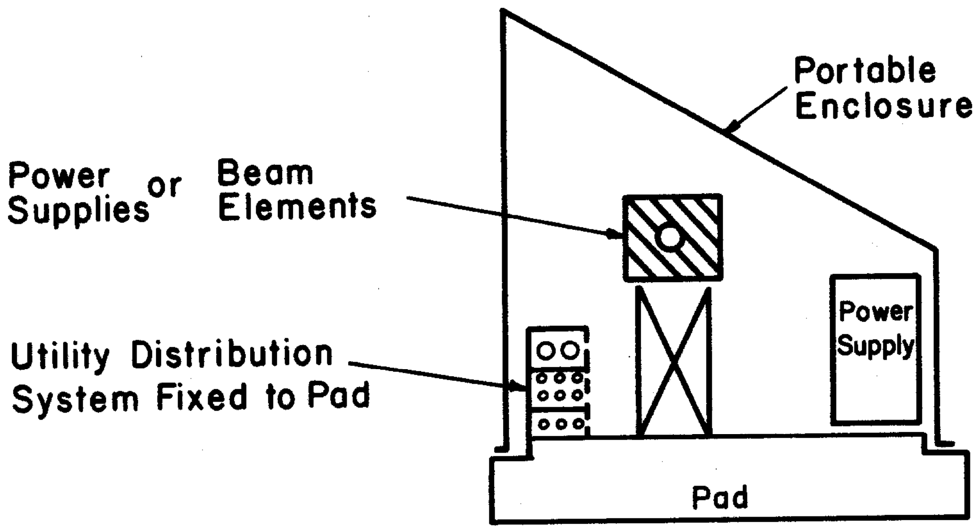


Fig. 3. General plan of the "A" station.





Cross Section jj

Fig. 4. Method for servicing experimental areas with utilities.

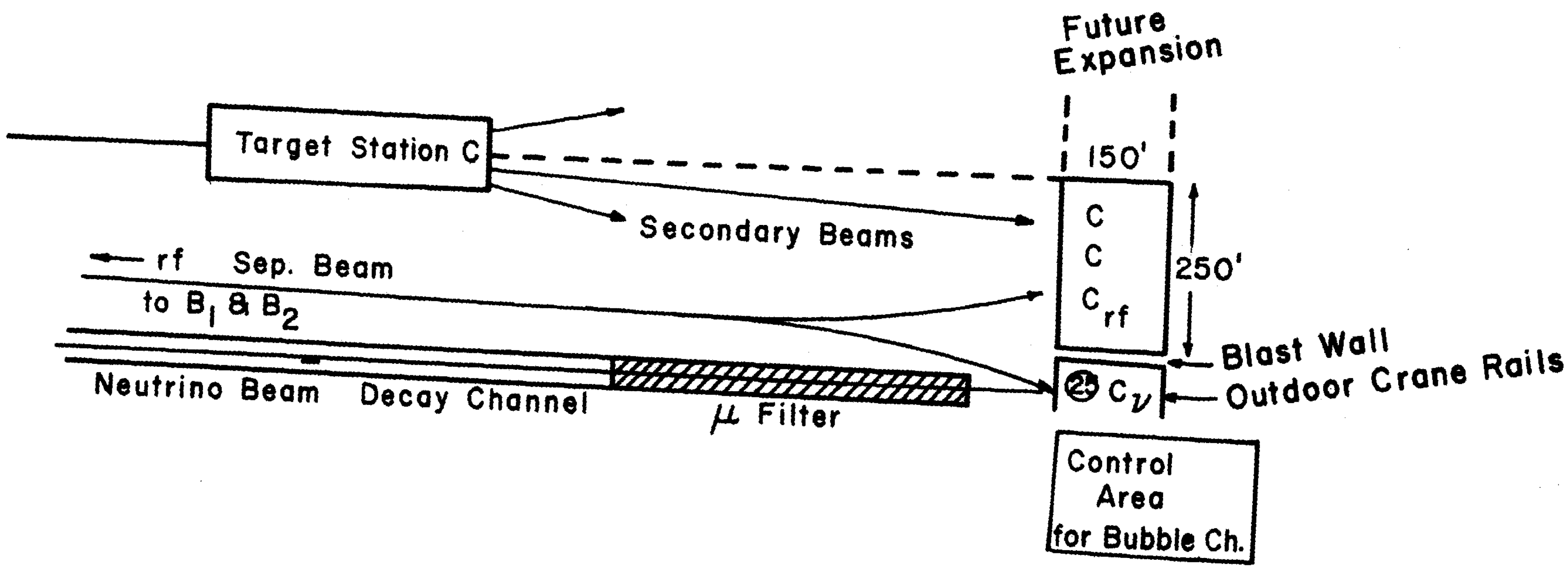


Fig. 5. Beam, target station, and large detector areas.

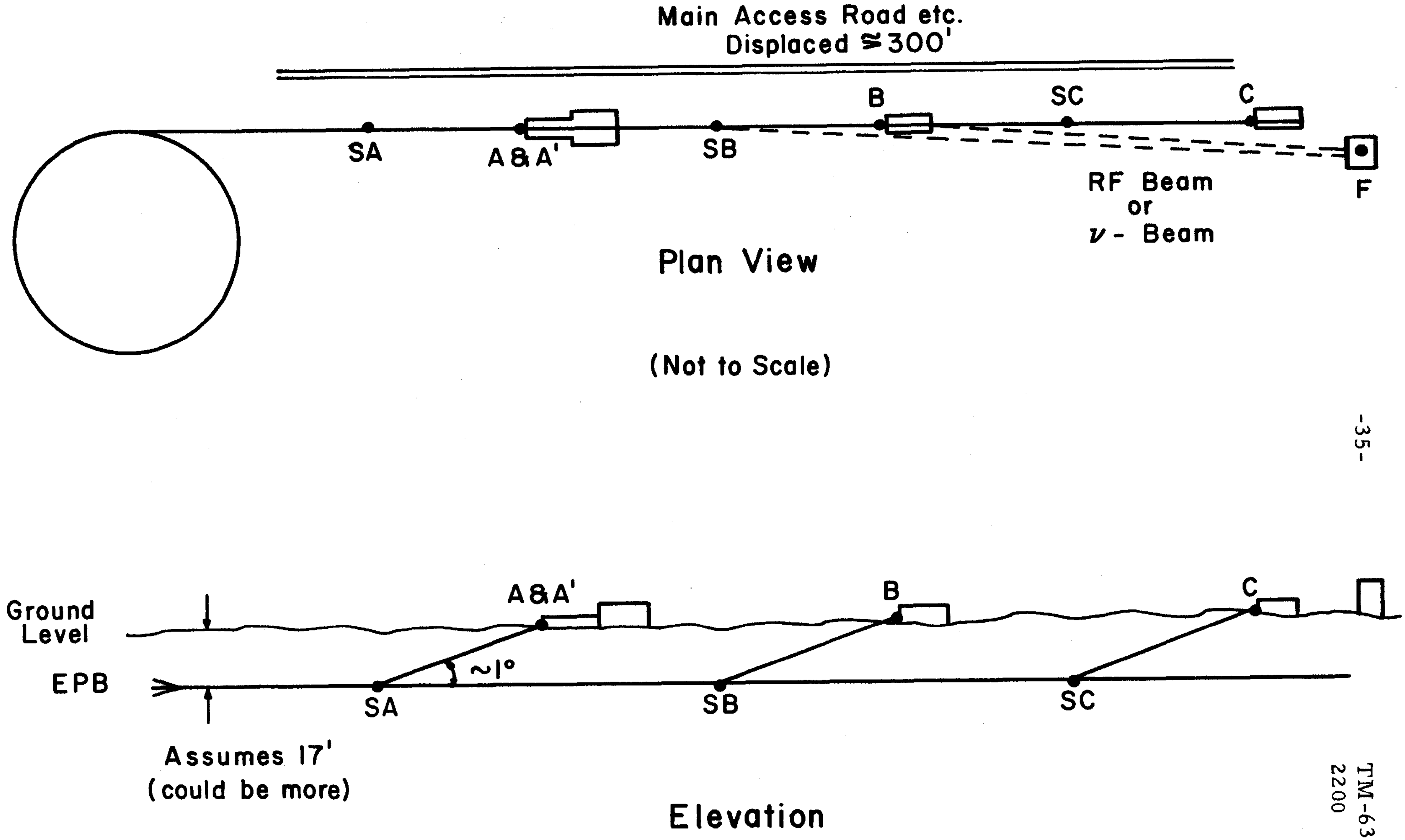


Fig. 6. Alternate general layout scheme.

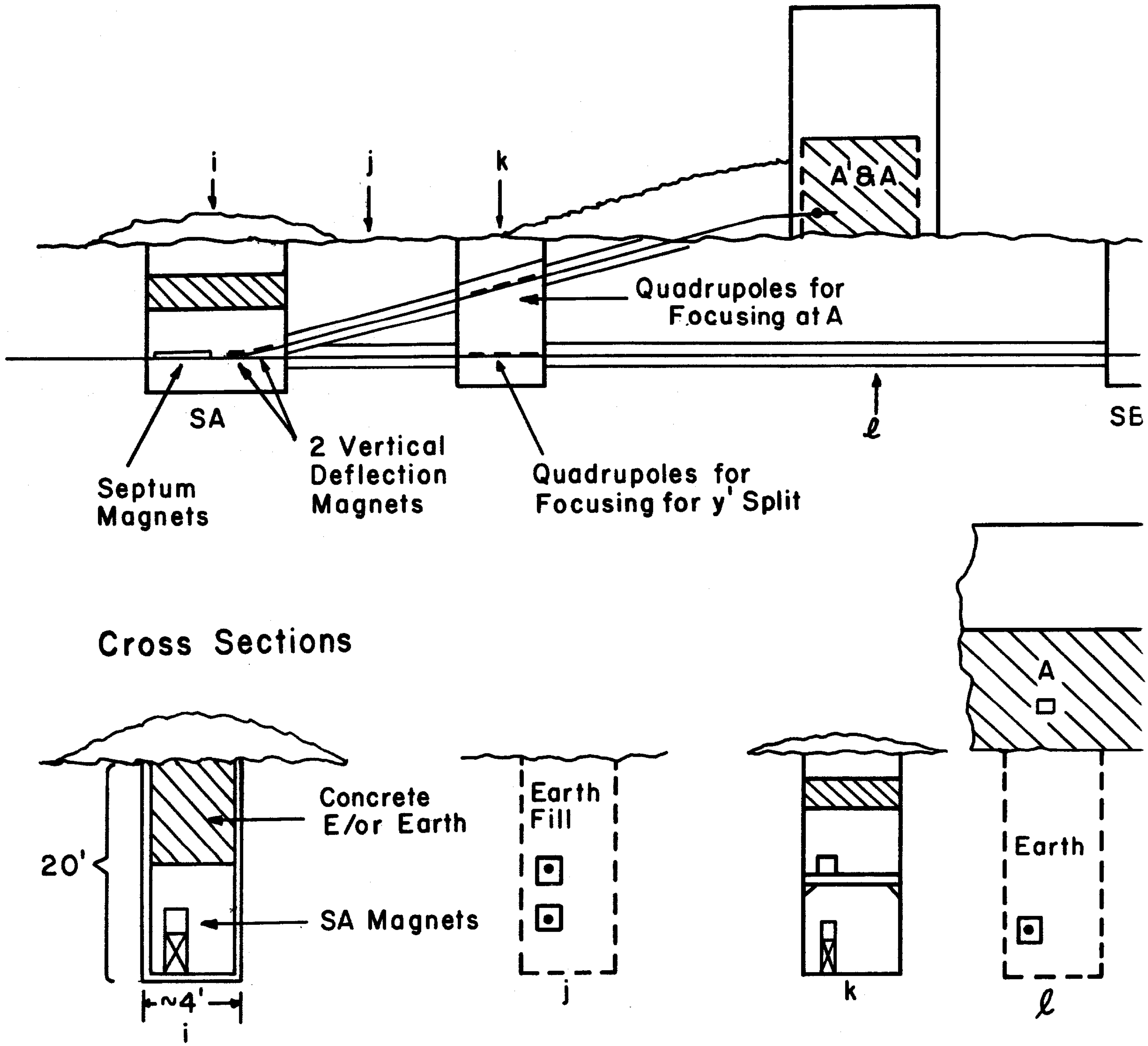


Fig. 7. Heavy target-station arrangement for beam splitting in the vertical plane.

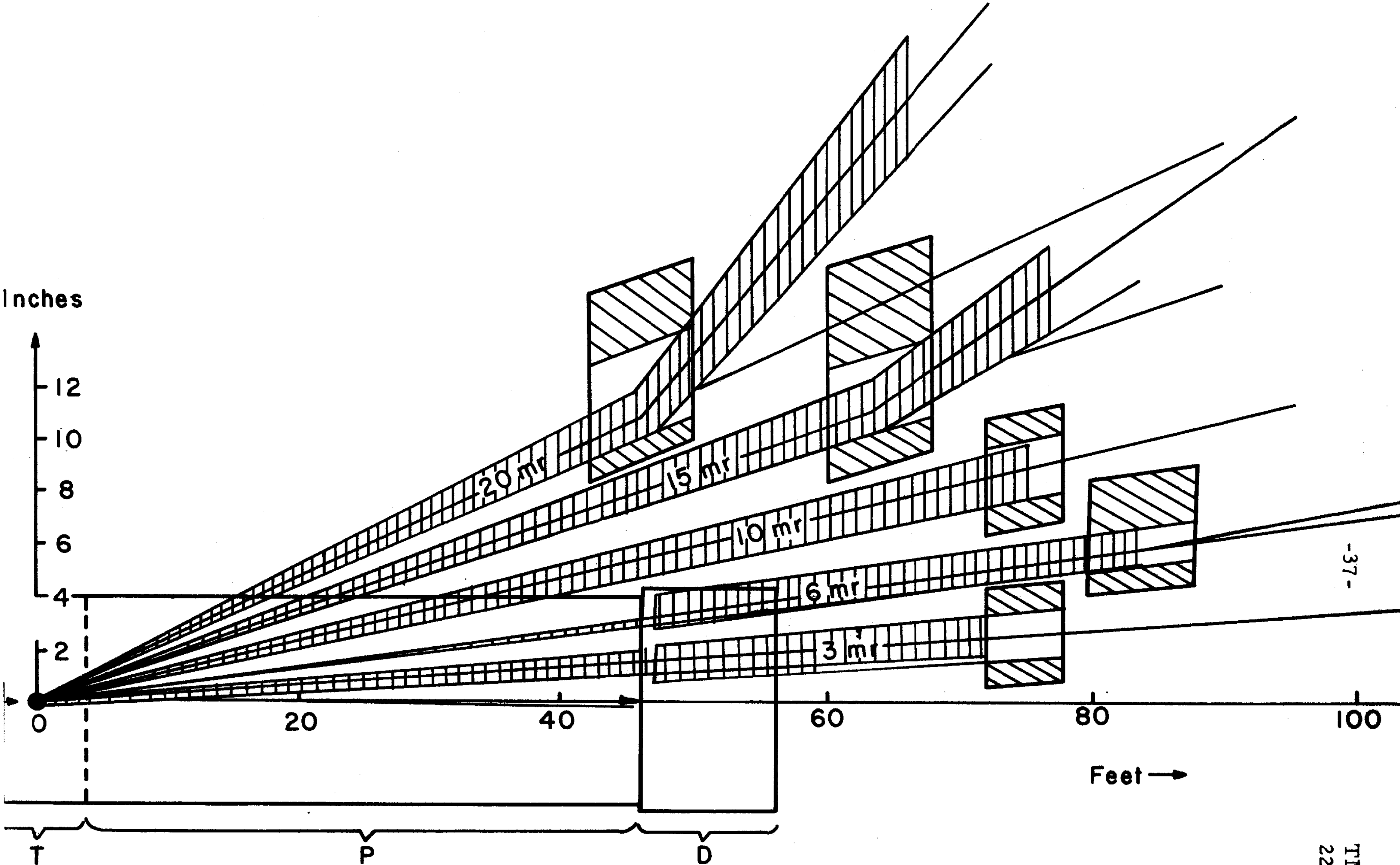


Fig. 8. A schematic layout possibility for a target area.