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PROTON THERAPY FACILITY

FERMI NATIONAL ACCELERATOR LABORATORY

Proposal for a

PROTON BEAM THERAPY FACILITY

October 9, 1984

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Proposal for a

PROTON BEAM THERAPY FACILITY

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INTRODUCTION

It is proposed to build a regional outpatient medical clinic at the Fermi National Accelerator Laboratory (Fermilab), Batavia, Illinois, to exploit the unique therapeutic characteristics of high energy proton beams. The Fermilab location for a proton therapy facility (PTF) is being chosen for reasons ranging from lower total construction and operating costs and the availability of sophisticated technical support to a location with good access to patients from the Chicago area and from the entire nation (Appendix B1).

Studies indicate that the population of the midwest alone can generate a sufficient annual patient referral rate to allow efficient operation of the PTF and meet its operational expenses (Appendices B2, B3 and B4).

MEDICAL JUSTIFICATION

Proton therapy beams are unique in radiation therapy. They can be designed so that they can deposit their energy in sharply defined volumes of tissue and, of all the so called heavy ion beams, they are the least expensive to construct (Appendix B5).

Presently, clinical proton beams are being used in the USA,[1] Japan,[2] Sweden,[3] and Russia.[4] They are routinely and effectively used as a tool to perform non-traumatic surgery in the treatment of arteriovenous malformations (AVMs) of the brain[5] and hyperactive pituitary glands,[6] and also for the local treatment of cancerous tumors such as ocular melanomas.[7] There are other possible applications of proton beams in non-traumatic brain surgery and in the therapy of cancer which are in the research stage (Appendix B6). The proton beams can be used to deliver radiation doses to target volumes surrounded by radiation sensitive tissues/organs without causing ill effects in these tissues. This includes cases where very large doses are not needed but critical structures must be avoided. It is expected that about 700 to 800 patients could be referred annually to the PTF by the fifth year of operations.

PLANT AND EQUIPMENT

This outpatient facility is envisioned as a modern facility designed for efficient and highly reliable, but austere, operations. The new plant will consist of beam enclosures, beam transport lines, treatment rooms and a small, but expandable, two story medical building incorporating facilities for patient related activities as well as dosimetry and treatment planning (Appendix B7).

From the point of view of costs, one must differentiate between the plant and equipment items which (a) now exist and (b) those which must be built or purchased.

(a) Now exist. This includes the 203 MeV proton linear accelerator and its enclosure, power and cooling, as well as all the ancilliary support equipment and computer controls.

(b) To be built or purchased. This includes beam enclosures at ground level, radiation shielding, beam transport lines (mostly using surplus equipment) (Appendices B8 and B12), dose delivery equipment, treatment rooms (Appendix B9), fixtures to position patients, verification X-ray equipment, computers for control and treatment planning, a medical building (Appendix B10) and miscellaneous equipment and furniture (Appendix B13).

COSTS OF CONSTRUCTION AND COMMISSIONING

The total PTF construction and commissioning costs are estimated to be M$ 8.2, in 1985 dollars (Appendix B11).

NOTE: Overhead rates used in this calculation are consistent with Fermilab FY'84 experience. Substantial changes in the Fermilab rate for future years are not anticipated.

ESTIMATES OF OPERATIONAL EXPENSES AND GROSS INCOME DURING OPERATIONS

Detailed estimates of operational expenses and income during therapy operations in project years 03 through 07 are given in Appendices B3 and B4. The stated overhead has not yet been approved either by the Director's Office or the Business Office. Therefore, it may be subject to change.

Calendar Year	1987	1988	1989	1990	1991
Operational Year	*2H03	04	05	06	07
Expenses** (M$)	1.14	2.4	2.6	3.1	3.6
Gross Income (M$)	0.82	2.6	4.3	5.8	7.4

Notes
* 2H03 means 2nd half of year 03.
** Insurance expenses have not been included.

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APPENDIX B1

ADVANTAGES OF LOCATING THE PTF AT FERMILAB.

(1) Reduced construction and operating costs. Construction costs will be lower than elsewhere since there would be no costs for either land or for construction of a very reliable accelerator. At Fermilab a 203 MeV linac now exists and has an excellent record for reliability. It has been in operation up to 168 hours per week for 13 years. It is part of the injector to the 1 TeV proton synchrotron. This linac is now in use for medical research on a part time basis. In addition, operational costs will be smaller since the linac has to be maintained for the high energy research program.

(2) Independence of Operation: regional/national resource. The nature of the diseases that have been proven to be ideally suited to proton therapy, is such that no single medical institution could generate sufficient demand to operate a PTF efficiently. Therefore, a PTF must be effectively created as a regional/national facility and, preferably, operated independently of any one medical institution.

(3) Experience as a regional/national resource. Essentially, the same team that has been operating the Fermilab Neutron Therapy Facility (NTF) is now proposing to build and operate the PTF. The NTF has been operated from its beginning as a regional/national resource. During its eight years of operations, over 1400 patients from 23 states and 5 foreign countries have been referred to the NTF for treatment. This experience insures that the proposed PTF will be well regarded by the medical community and that numerous patients may be referred to it for therapy. It should be understood that the use of a proton beam for therapeutic purposes is much more sophisticated and demanding than the clinical use of X-ray, electron or neutron beams. More physics support of higher quality than is commonly needed in standard radiation therapy facilities will be needed. Some of this support will be independent of the number of patients actually treated.

(4) Proven successful dealings with regional and national physicians. When the NTF was being organized meetings were carried out with all the area radiation therapists willing to attend. From those meetings a number of advisory committees were created and excellent relations were established and maintained. Already, three advisory groups have been informally created for the PTF, one for neurosurgery (AVMs, pituitary, etc.), another for ophthalmology and a third one for radiation oncology. The current groups consist of the heads of the appropriate departments of each of the eight Chicago medical schools. The membership of these groups may be expanded in the future.

(5) High technology support. Fermilab possesses a cadre of physicists, engineers, technicians, machine and electronics shops accustomed to work at the frontier of technology. Hence, any proposed plans for beam transport and/or dose delivery systems will very likely be successfully finished on schedule and within their budgets.

(6) Research environment. The atmosphere of research that pervades Fermilab is an imponderable but significant asset to any high technology research program.

(7) Geographical location. The Fermilab PTF would be located within a one to two hour driving time from most points of the greater Chicago and one hour from the O'Hare Airport, the busiest in the world. Therefore, this geographic location is quite satisfactory since the type of patients who would use the facility would be ambulatory and many of them would need only one visit to the PTF.

(8) Patient availability. The availability of potential patient referrals was evaluated by the consulting firm of Amherst Associates. This study showed that up to a thousand patients per year might be referred to the Fermilab PTF (Appendix B2). This would allow the PTF to be self sufficient in meeting operational costs while providing medical care less expensively than using conventional procedures.

APPENDIX B2

ESTIMATE OF NUMBER OF ANNUAL PATIENT REFERRALS.

This work was performed by the consulting firm of Amherst Associates, Inc., (140 South Dearborn Street, Chicago, IL 60603) and completed in January 1984.

The estimated numbers of patient referrals were obtained from an analysis of the experience at the Harvard Cyclotron Laboratory and the Massachusetts General Hospital (HCL-MGH). It was assumed that population use rates for medical services and market shares, e.g., fraction of the population that would use the Fermilab PTF would be about the same as for the HCL-MGH facility as a function of distance.

Projections were made of population growths within rings with radii of 200, 400, and 800 miles for years between 1986 and 1991.

It should be mentioned that there will be a difference in the manner of operations between the PTF and the HCL-MGH. At the HCL-MGH there is one neurosurgeon in charge of all AVMs and pituitary work. Similarly, patients with eye melanomas have to be referred to the Massachusetts Eye and Ear Infirmary to have access to the HCL-MGH facility. The Fermilab PTF, being operated as a national resource, will not be affiliated with any medical institution. This may bring a larger number of referrals for a given population base than at the HCL-MGH.

Proton beam treatments for AVMs, hyperactive pituitary glands and ocular melanomas are proven modalities and there is a long experience at the HCL-MGH.

Treatment of prostatic, brain and CNS, and other tumors as well as aneurysms at the base of the brain are new or unproven techniques and estimates of referrals are not firm.

The results of the Amherst Associates study are presented graphically on the last page of this Appendix.

In determining the number of annual patient referrals at the PTF the Amherst Associate estimates were used as follows,

(a) for AVMs, hyperactive pituitary glands and eye melanomas the estimated referral rates were taken as given in the report,

(b) for prostatic and brain/CNS tumors the rates were taken as one-half of ones estimated by Amherst Associates,

(c) for large field fractions the HCL-MGH rate was doubled because of the regional/national nature of the proposed facility.

Thus, it is believed that a conservative patient load is being used to estimate the facility utilization, operational costs and gross income.

The table below not only summarizes these estimates but also gives estimated number of fractions per course of treatment to permit estimating the daily patient load at the facility.

It is expected that the facility will operate four days per week, fifty weeks per year.

Calendar Year		1987	1988	1989	1990	1991	
Operational Year		2H03*	04	05	06	07	
(5)**	Ocular melanomas	29	100	144	169	194	
(1)**	AVMs/pituitaries	37	97	121	144	171	
(12)**	Prostatic tumors	17	75	151	207	262	
(5)**	Brain/CNS tumors	3	14	29	39	50	
(10)**	Lg Field Research	15	40	75	125	150	
Totals	No. of patients/yr	101	326	520	684	827	
No. of fractions/yr		551	1967	3548	4918	6035	
No. of fractions/day		6	10	18	25	30	
No. of new patients/day		1	1.6	2.6	3.4	4.1	
No. of treatm. rooms needed		1	1	1	2	2	
No. of rad. therapists needed		1	1	1	2	2	
Research pts. as % of all pts.		15	12	14	18	18	<P>=15%
Research fxs. as % or all fxs.		27	20	21	25	25	<F>=24%

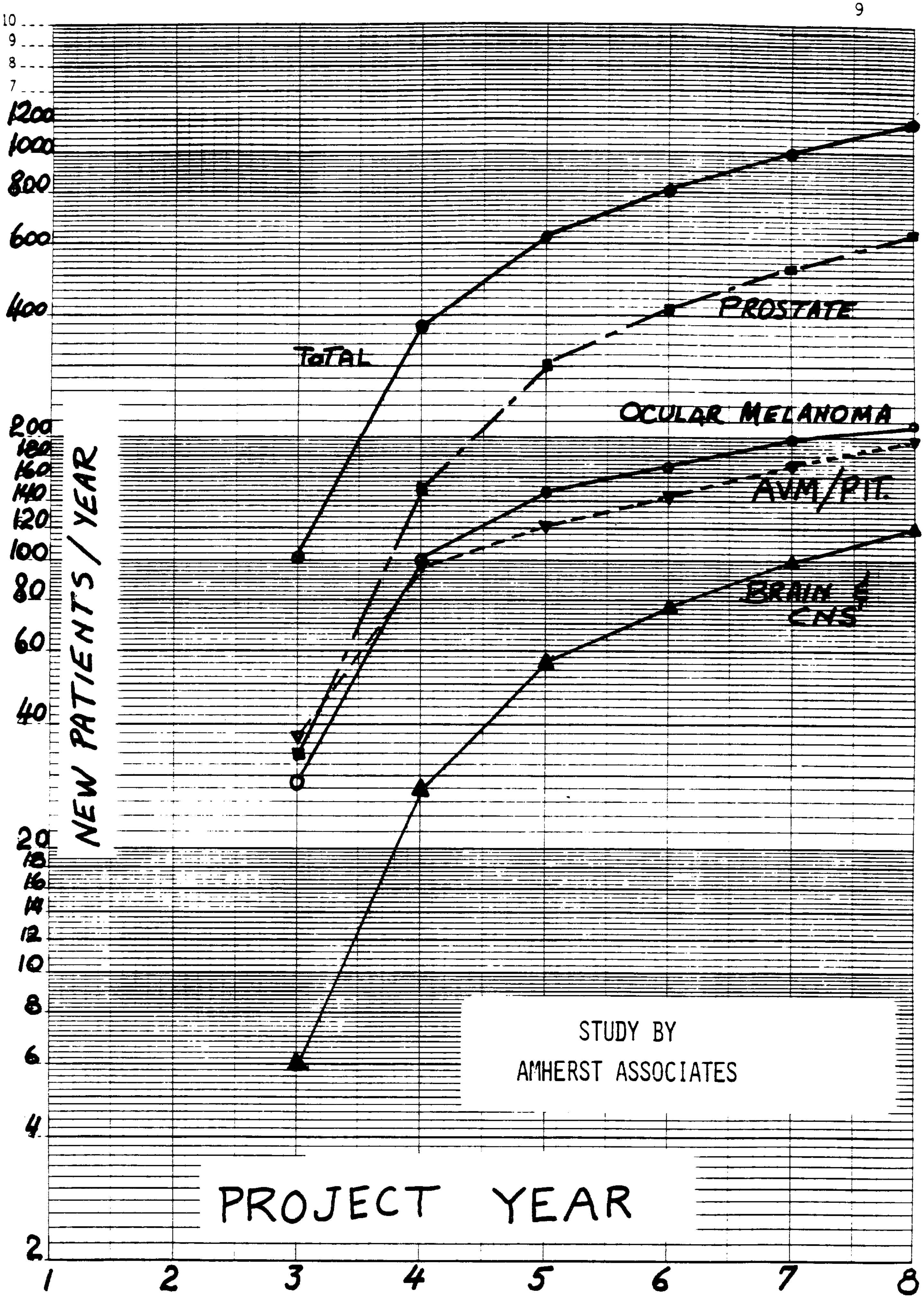
Notes:

* 2H03 means second half of year 03.

** Number of fractions per course of treatment. It is assumed that part of the dose is given with photons or electrons.

pts = patients, fxs = fractions.

<P>, <F> = average number of research patients/research fractions as a percentage of all patients/fractions.



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APPENDIX B3

ESTIMATE OF OPERATIONAL EXPENSES

1. Expected number of patients. See table in Appendix B2.

2. Estimate of proton beam usage and beam costs.

Calendar Year	1987	1988	1989	1990	1991	
Operational Year	2H03	04	05	06	07	
Therapy time*	326	1084	1874	1280**	1560**	hrs
Dosimetry time	208	100	100	100	100	hrs
Total time	534	1184	1974	1380	1660	hrs
Beam cost	223	239	256	274	293	hrs
Total cost	.119	.283	.505	.378	.486	M$

* 1/2 hr per fraction + 1/2 hr/day for calibration.
** Two therapy rooms in use. 2H03 means second half of year 03.

3. Personnel Requirements.

Calendar Year	1987	1988	1989	1990	1991
Project Year	2H03	04	05	06	07
Est. No. of fractions/day	6	10	18	25	31
Est. No. of new patients/day	1	1.6	2.6	3.4	4.1
a. Physicians	1.4	1.4	1.4	2.4	2.4
b. Physicists/Programmers	4	4	4	4	4
c. Rad. Therapy Techs	2	2	2	5	5
d. Electronics Techs	2	2	1	1	1
e. Clerical/Billing	1	2	2	2	2
f. Dosimetrist	1	1	1	1	2
g. Machinist	1	1	1	1	1
h. Nurses/Data Manager	1	2	2	2	2
i. Draftsman	1	1	-	-	-
j. Mechanical Engineer	1	1/2	-	-	-

4. Salary and Fringe Benefit Estimate. These salaries include 25% for fringe benefits.

Calendar Year	1987	1988	1989	1990	1991
Project Year	2H03	04	05	06	07
a. Physicians	69	147	157	288	309
b. Physicist/Programmers	184	393	421	450	482
c. Rad. Therapy Techs	49	105	112	300	321
d. Electronics Tech	36	76	41	44	47
e. Clerical/Billing	42	89	95	102	109
f. Dosimetrist	20	44	47	50	108
g. Machinist	23	49	52	56	60
h. Nurses/Data Manager	48	102	109	116	125
i. Draftsman	18	37	-	-	-
j. Mechanical engineer	36	38	-	-	-
Subtotals (k$)	525	1080	1034	1406	1561

5. Estimate of Operational Expenses During Operations (Therapy Phase) in M$.

Calendar Year	1987	1988	1989	1990	1991
Project Year	2H03	04	05	06	07
a. Salaries	.525	1.080	1.034	1.406	1.561
b. Beam cost	.119	.283	.505	.378	.486
c. Supplies	.032	.088	.094	.101	.108
d. Travel	.010	.036	.039	.041	.044
e. Equipment	.030	.040	.043	.046	.049
f. Insurance	?	?	?	?	?
Subtotal	.716	1.527	1.715	1.972	2.248
g. Overhead(35% of A,C&D)*	.198	.421	.408	.542	.600
Subtotal	.911	1.948	2.123	2.514	2.848
h. 25% Contingency	.229	.487	.531	.629	.712
Total	1.140	2.430	2.650	3.143	3.560

Note:
* Overhead rates used in this calculation are consistent with Fermilab FY'84 experience. Substantial changes in the Fermilab rate for future years are not anticipated.

APPENDIX B4

ESTIMATE OF OPERATIONAL GROSS INCOME

As discussed in Appendix B2, the total number of procedures has been mostly derived from the Amherst Associates report.

Proven procedures. This includes AVMs, hyperactive pituitary gland and ocular melanoma treatments. The gross income per procedure is a combination of HCL-MGH practices and local estimates.

Other procedures. These include prostatic and brain/CNS tumors as well as research involving large treatment fields, lines 3, 4 and 5, in the table of Appendix B2. The gross income per procedure is a local estimate based on the Neutron Therapy Facility experience.

Cal. Yr.	Oper. Yr.	OC(1) Pts.	k$ (2)	AVM/pit Pts.(3)	k$ (4)	Other Pts.	k$ (2)	Total M$ Income
1987	2H03	29	5.2	37	13.1	35	5.2	0.82
1988	04	100	5.6	97	14.0	129	5.6	2.6
1989	05	144	6.0	121	15.0	255	6.0	4.3
1990	06	169	6.4	144	16.0	371	6.4	5.8
1991	07	194	6.9	171	17.2	462	6.9	7.4

Notes:
(1) OC = ocular melanomas.
(2) Cost per procedure, based on 4k$ in 1983.
(3) Arteriovenous malformations and hyperactive pituitaries.
(4) Cost per procedure, based on 10k$ in 1983.
2H03 means second half of year 03.

APPENDIX B5

ADVANTAGES IN USING PROTONS FOR RADIOTHERAPY.

Protons were first proposed for radiation therapy by R. R. Wilson, director emetrius of Fermilab, in 1947.[1] Vis-a-vis x-rays, electron and neutron beams, its advantages are,

1 - Range.

(a) X-rays and neutrons are absorbed in a medium in proportion to their number present at any depth. Therefore, they are attenuated as a function of depth but never totally absorbed or stopped. Thus, x-ray and neutron beams do not have a distal edge.

(b) Electrons mostly lose their energy by collision with electrons of the medium. In these collisions they can lose from zero to their full energy. As a consequence, incident monoenergetic electrons soon acquire a continuum of energies and they stop at a rather wide continuum of depths. Hence, their range is not well defined and the distal edge of the beam may extend from many millimeters to centimeters.

(c) Protons of 203 MeV and lower energy also lose most of their energy by collisions with electrons of the medium. But, protons have a mass almost 2000 times larger than that of an electron. Therefore, in each collision with an electron they only lose a small fraction of their energy. Hence, before stopping, they have made very many collisions. This causes protons to have a very well defined range, i.e., a sharply defined distal edge.

2 - Lateral spread.

The laws of motion describing the collisions between x-rays and electrons with electrons, and neutrons with nuclei allow the scattering of the electrons or nuclei at large angles to the direction of the incident particle. Therefore, x-ray, electron and neutron beams have rather large lateral spreads. These lateral spreads may be many millimeters wide from the 90% to the 20% dose levels.

In the case of protons their large mass again prevents them from changing directions significantly after a collision with an electron. Hence, lateral spreads of less than 1 mm are possible in proton beams.

Heavy ions such as nuclei of helium, carbon, neon or silicon atoms have ranges and lateral spreads that are even sharper than those of protons. However, it still remains to be proven that these increases in geometric beam sharpness have any clinical advantages.

REFERENCE

1. R. R. Wilson, Radiological Use of Fast Protons, Radiology 47, 487 (1946).

APPENDIX B6

PROPOSED RESEARCH PLANS AT THE PTF.

In an environment where charged particle beams are available for therapeutic purposes, the term radiation therapy implies radiation oncology as well as radiation surgery.

A. THE PROTON BEAM AS AN ONCOLOGICAL TOOL.

The following research program was written by Lionel Cohen, M.D., Director of the Radiation Therapy Department of the Michael Reese Medical Center, Chicago, IL.

It is recognized that the use of high energy proton beams to irradiate large volumes of tissue to uniform high doses has the potential for long-term control or even cure of many late stage cancers which would not be amenable to conventional radiation therapy. Tumors are roughly classified into three categories, (1) radiosensitive tumors which respond well to relatively small doses of radiation well within normal tissue tolerance limits and are consequently readily controlled by conventional megavoltage photon or electron beam therapy, (2) radioresistant tumors which are not amenable to conventional radiotherapy and may be more responsive to high LET radiations, and (3) a large intermediate group of moderately responsive tumor types which are readily cured in the early stages but present insuperable problems in their management when they reach a large size. It is this latter group of tumors in which the availability of a proton beam facility is likely to yield markedly improved local control rates. This arises from the well established radiobiological and radiotherapeutic phenomenom in which the tumor response in relation to normal tissue tolerance is critically related to the size of the target volume. For example, with small epidermoid carcinomas (say, 1 cm^3 volume) a tumor dose of 60 Gy delivered in 25 or 30 daily fractions will yield long-lasting local control in the majority of patients. Since, in their regular course of treatment, each fraction depletes the cell population by a constant factor, the dose required to yield an equivalent cure rate would be proportional to the logarithm of the tumor cell population. Thus, if 1 cm^3 of tumor contains 10^8 viable clonogenic tumor cells and can be controlled by a dose of 60 Gy, then a 1000 cm^3 tumor containing 10^{11} cells, would require 60 x 11/8 = 82.5 Gy. At the same time the normal tissues traversed by the beam, which are well able to tolerate 60 Gy delivered to a relatively small volume, are very likely to be severely compromised by any attempt to deliver 80 or more Gy to the correspondingly larger volume.

The situation is further complicated by the inevitable inhomogeneity in dose distribution throughout large target volumes. While it might be possible to irradiate the smaller volume uniformly to the required dose of 60 Gy, it becomes impossible in practice to deliver uniform irradiation to large or irregularly shaped target volumes. In practice a dose variation (ratio of some 20-30%) is unavoidable. A minimal tumor dose of 82.5 Gy may well represent a maximum dose at some point within the irradiated volume of 100 Gy or more. These constraints often render it impossible to treat a large, albeit relatively responsive, tumor adequately with conventional photon or electron beams. One of the major advantages of proton beam therapy would be the feasibility of irradiating large, irregularly shaped volumes with great uniformity (in this context meaning a variation of dose not greater than, say, 5% across the target volume). This advantage is likely to be realized in the case of late stage epidermoid carcinomas in various sites. These sites are identified below, and a trial of proton beam therapy in each of them delivering the computed optimum dose (60 to more than 80 Gy depending on tumor volume) with a high degree of uniformity across a well-defined target volume would appear to be promising.

The biological effects of proton doses are very similar to those of photon and electron beams. Therefore, it might be advantageous or simply more convenient, at times, to combine protons and photons or electrons. Furthermore, shrinking field techniques using protons only might be very effective.

The following sites which are commonly affected by late stage epidermoid carcinoma would be studied.

1) Late Stage Epidermoid Carcinoma of the Head and Neck.

Locally advanced epidermoid carcinomas of the buccal cavity, pharynx, or supraglottic larynx, with or without regional nodes, represent typical tumors of the type most likely to be amenable to proton beam therapy. These tumors are invariably large and require high doses (computed to be on the order of 80 Gy) for their control, while at the same time being contiguous to normal tissues such as the buccal mucosa, mandible and cartilaginous larynx which are intolerant to these high doses. They are also relatively close to vital structures such as the spinal cord (tolerance limit 50 Gy) which impose further constraints on the conventional treatment plan. With proton beam therapy such tumors could probably be irradiated uniformly to the required tumor dose without compromising adjacent normal tissues unduly.

2) Carcinoma of the Lung.

Cure rates in the treatment of lung cancer are notoriously low because of failure to achieve local control and the onset of distant metastases in approximately equal proportions. Local failure may be attributed to the fact that it is difficult to achieve doses greatly in excess of 50 Gy to the large irregularly shaped target volume without compromising adjacent structures. In late stages where the disease tends to affect mediastinal nodes bilaterally, the use of the spinal shield, necessitated with anteroposterior fields, inevitably shadows and underdoses at least part of the tumor. Similarly, the use of unilaterally oblique fields often fails to irradiate the contralateral mediastinal lymph nodes. These compromises could be overcome by uniform proton irradiation of both the primary site and regional nodes, without compromising adjacent structures, and should permit delivery of much higher doses, possibly approaching the theoretical optimum of some 70-80 Gy. One might expect a higher rate of local control to be achieved, and this would have the advantage of prolonging life in patients who do not have metastases but also rendering the feasibility of elective chemotherapy more practical in those patients with residuals of clinical disease.

3) Carcinoma of the Esophagus.

This tumor resembles lung cancer in its propensity for regional extension into the mediastinum and the difficulty in delivering adequate dosage to the entire affected, or potentially affected, region. For the same reasons proton beam therapy promises to be much more effective in this location.

4) Carcinoma of the Pancreas.

Local control in this area is difficult because of the relative intolerance of adjacent organs which limit the amount of radiation which can be delivered to the tumor and immediately adjacent tissues. Local control rates with the best available precision high dose radiotherapeutic techniques are of the order of 20% whether photons or neutrons are used. Where higher doses can be delivered by means of brachytherapy, implants or intraoperative radiotherapy higher control rates have been reported. These techniques are not feasible where the tumor is large or has invaded adjacent tissues. In these instances the only feasible approach to high local dose is with charged particle beam irradiation. A proton facility would be advantageous in the management of nonresectable pancreatic carcinoma. If local control can be achieved in this condition then the feasibility of systemic chemotherapy for the retardation or prevention of distant metastases could be explored vigorously.

5) Pelvic Tumors.

Malignant tumors of the uterus, bladder and prostate would be expected to benefit from the intensive radiation to irregular target volumes provided by high energy proton irradiation. With late stage epidermoid carcinoma of the cervix the limiting constraint militating against successful control is the same as with epidermoid cancer in other sites, namely the need to deliver large doses without compromising adjacent normal structures. In the case of the cervix it would be advantageous to deliver doses of the order of 80 Gy to the tumor and parametria while avoiding heavy irradiation of the bladder and rectum. Similarly the control of bladder cancer would be expected to be improved if the organ could be uniformly irradiated while avoiding radiation injury to adjacent organs such as the rectum. The same argument applies in the case of the prostate, in which small tumors are readily controlled but the high doses required for ablation of large prostatic tumors often exceed the limits of tolerance of pelvic structures. In all these sites there is a clear theoretical advantage to be expcted with proton beam irradiation.

In addition to the five specific regions sited, proton beams would have a particular advantage in almost any tumor growing in close proximity to a sensitive normal structure. This situation is frequently manifest in the case of tumors of the vetebral column (sarcomas, chordomas) in which the close proximity to the spinal cord usually precludes adequate treatment. These situations are particularly amenable to proton beam therapy with its capability for uniform irradiation of irregularly shaped target volumes which can be precisely demarcated from surrounding structures.

B. THE PROTON BEAM AS A SURGICAL TOOL.

Expanding on the research already completed showing the excellent results from treating vascular malformations of the brain,[1,2] other vascular lesions unsuitable for surgery might be placed in a research protocol. These could include vascular aneurysms in inaccessible locations, i.e., base of brain. The vascular wall thickening seen in AVMs may reduce the risk of such aneurysms leaking.

For patients with disturbed brain functions specific destructive lesions in the brain often improve functions. These lesions are now produced by a surgical procedure often with electric current. A non-invasive approach to small destructive foci could be considered using the well-defined proton beam.

REFERENCES

1. R. N. Kjellberg, T. Hanamura, K. R. Davis, S. L. Lyons, R. D. Adams, Bragg-peak Proton-beam Therapy for Arteriovenous Malformations of the Brain, New England Journal of Medicine 309, 269 (1983).

2. C. G. Drake, Arteriovenous Malformations of the Brain, New England Journal of Medicine 309, 308 (1983).

APPENDIX B7

GENERAL DESCRIPTION OF THE PTF

1 - Medical Building.

This would be an austere two story 3800 net square feet building that would match the Fermilab architectural style used in the vicinity of the R. R. Wilson Hall.

Direct patient related activities (such as reception, waiting, examination, treatment planning areas) would be located on the first floor (Appendix B10). Support activities (such as dosimetry laboratory, medical records, supplies, and computer rooms as well as some staff offices) would be located on the second floor.

This building would be connected to the treatment rooms via a passageway. Also, it would be expandable to accommodate a greater patient load and larger staff.

2 - Treatment Rooms.

Two treatment rooms are planned and space will exist for a future variable pitch isocentric beam treatment room. Two treatment rooms are proposed from the start because the experience at the HCL-MGH is that with two treatment stations they cannot keep up with the demand for treatments and the waiting list is getting longer (private communication from A. Koheler, early 1984). Out estimates indicate a need for two treatment rooms after two and a half years of operations (Appendix B2).

The presently proposed treatment rooms would have two treatment stations (Appendix B9).
(a) Head and Neck Station. At this location, patient positioning fixtures will be optimized for the irradiation of arteriovenous malformations (AVMs), hyperactive pituitary glands, coroidal melanomas (eye melanomas) and, perhaps, aneurysms at the base of the brain. At this station the patients would be treated sitting down. The patient immobilization fixture (chair) would have such adjustments that isocentric (I/C) treatment planning and execution would be possible. The system for patient fixation would be designed to maximize accurate dose delivery to small volumes of tissue in the head and neck areas. Position monitoring may be remotely verified with x-rays via closed circuit TV.

(b) Couch Station. At this location, treatments could be delivered to any part of the body. However, the compromises needed for its use, would slightly decrease the precision of dose delivery. Patients could be irradiated lying down on their back, front, or side as well as sitting or kneeling down. A very flexible couch has been designed that not only permits those treatment positions but also dips (head to toes) $\pm 15^{o}$, and tilts (left-to-right) $\pm 15^{o}$, and would permit I/C treatment planning and execution.

Common to both stations would be closed circuit TV and intercom systems to allow general patient monitoring. Also, it will be possible to remotely make small adjustments of the patient positioning fixtures and check the effects of these adjustments via remote x-ray displays. This would permit greater efficiency in the utilization of the treatment rooms without compromising the quality of the treatment.

3 - Accelerator, External Beam Lines, Controls, Computer Support, Dosimetry, Computer for Treatment Planning, Miscellaneous.

The source of high energy protons would be the 203 MeV proton linear accelerator used at Fermilab as part of the 1 TeV accelerator system. Under normal circumstances, this linac is scheduled to operate 144 hours/week and it has a proven very high level of reliability, running 97% of the scheduled time. The beam would be extracted from the linac and carried to a level 54 inches above the floor of the medical building, where it would be rendered horizontal and a switch magnet would send it to either a temporary dump, one of two treatment rooms or a future isocentric beam treatment room (Appendix B8).

The proton beam lines, the dose delivery system and treatment room set-ups will be under computer control and/or monitoring. Treatment planning incorporating medical information from various sources such as CT, MRI, and ultrasound scanners will be done in three dimensions using a dedicated computer.

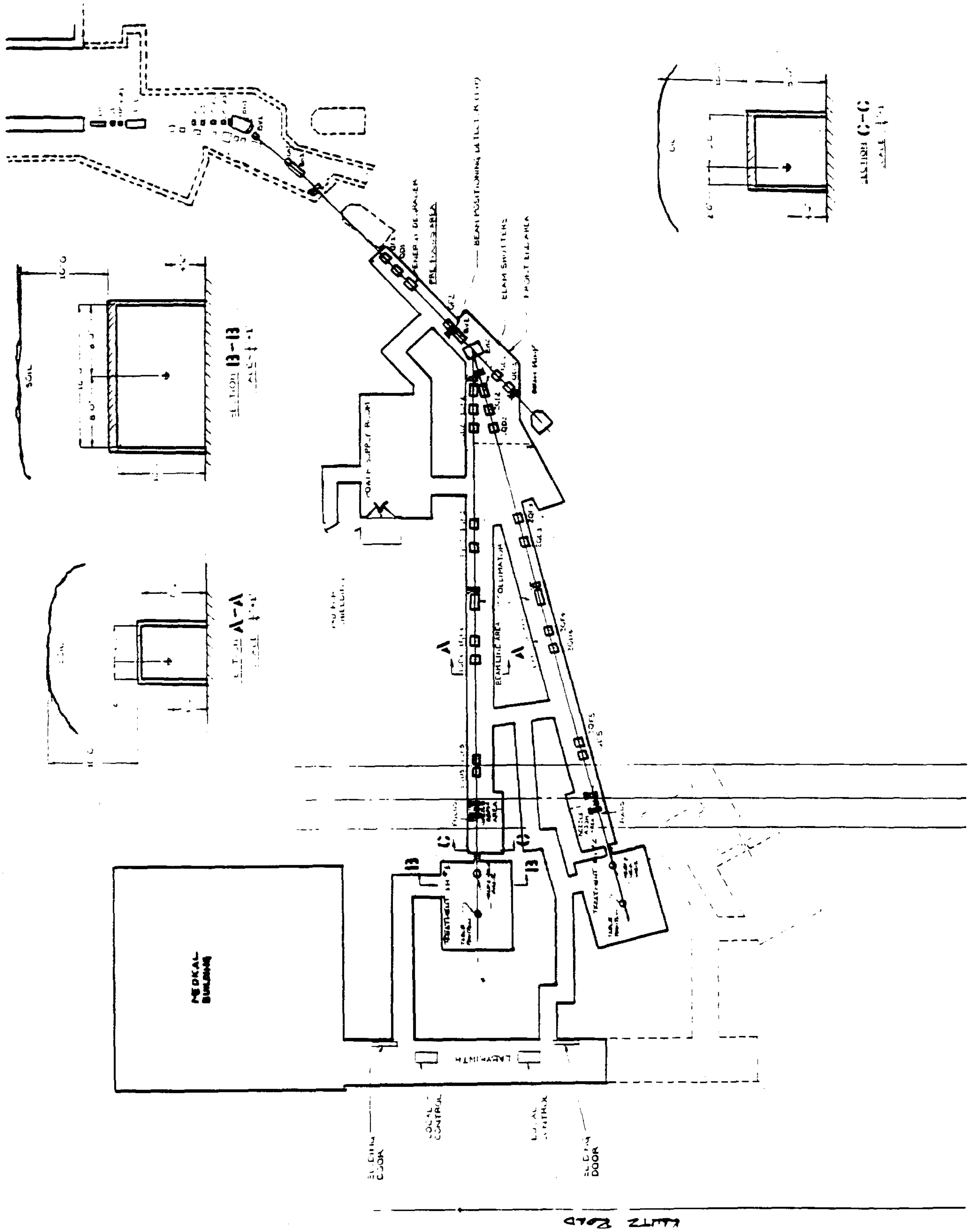
There will also be a dosimetry laboratory and a small machine shop to make beam compensators (boluses). It must be remembered that a bolus is generally needed for each treatment portal for each patient.

4 - Some Special Dose Delivery Features.

Treatment would include bolus to shape the distal surface of the beam. Dynamic collimation would reduce the dose to the proximal normal tissues. Simplified Bragg peak ranging is planned using a system involving binary range shifters and several double scattering nozzles with different beam dispersions mounted around an axis. All beam intensity measurements are to be made with hard vacuum SEMs instead of ionization chambers. For the treatment of ocular melanomas and of head and neck tumors, two dedicated beam "snouts" are planned for each treatment room. These snouts would be suspended from the wall using ball bushings and having complete sets of CCTV cameras, mirrors and what-nots to permit changes from one type of set-up to the next in about 60 seconds or less (Appendix B9). All radiographic equipment, except the machine for the in beam eye/head and neck monitoring, are to be wall mounted.

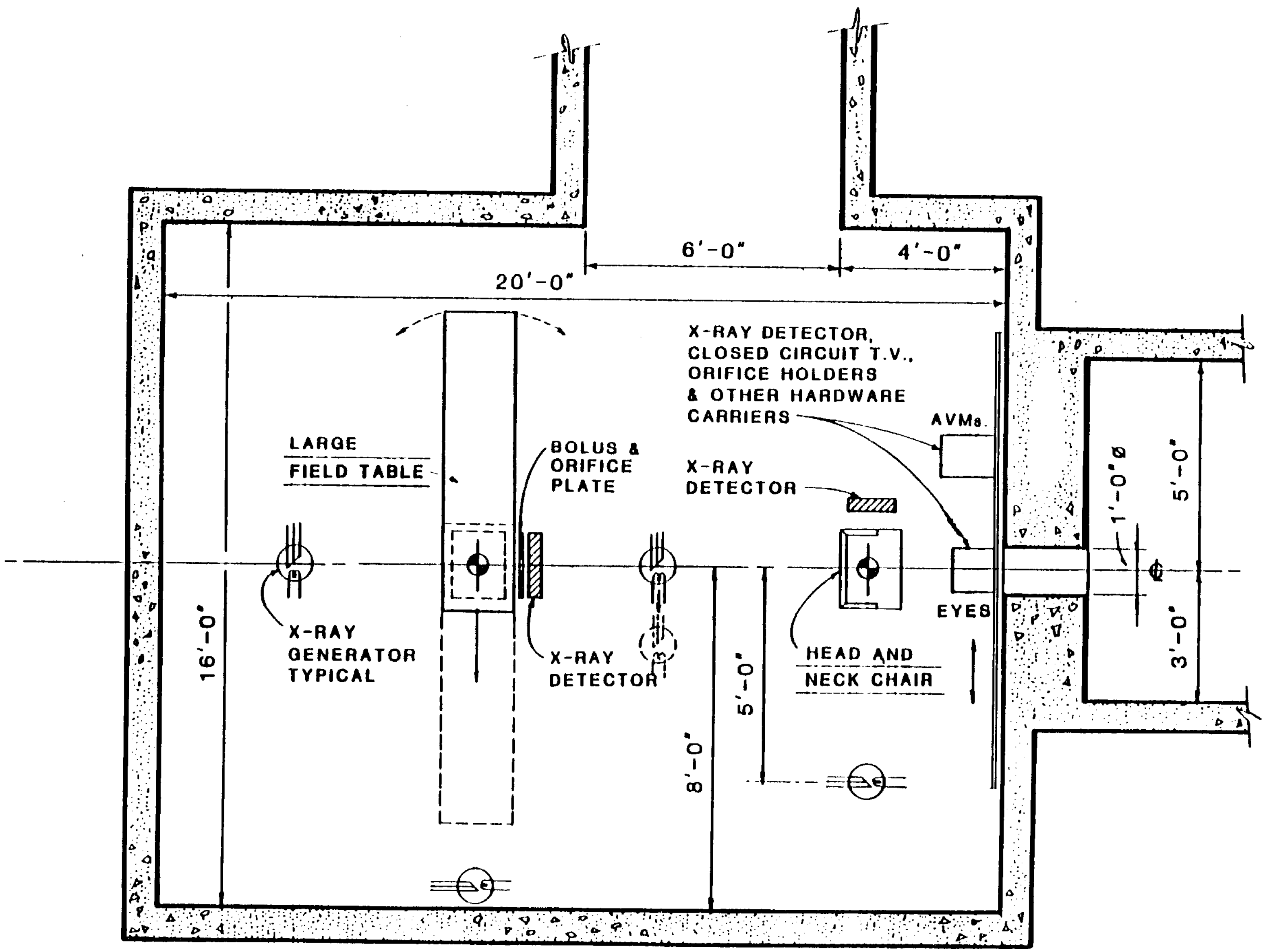
APPENDIX B8

BEAM LINES: LAYOUT.



APPENDIX B9

TREATMENT ROOMS: FLOOR PLAN



TREATMENT ROOM FLOOR PLAN

1/2"-1'-0" Scale 1 0 1 2 3 4 5 Feet

APPENDIX B10

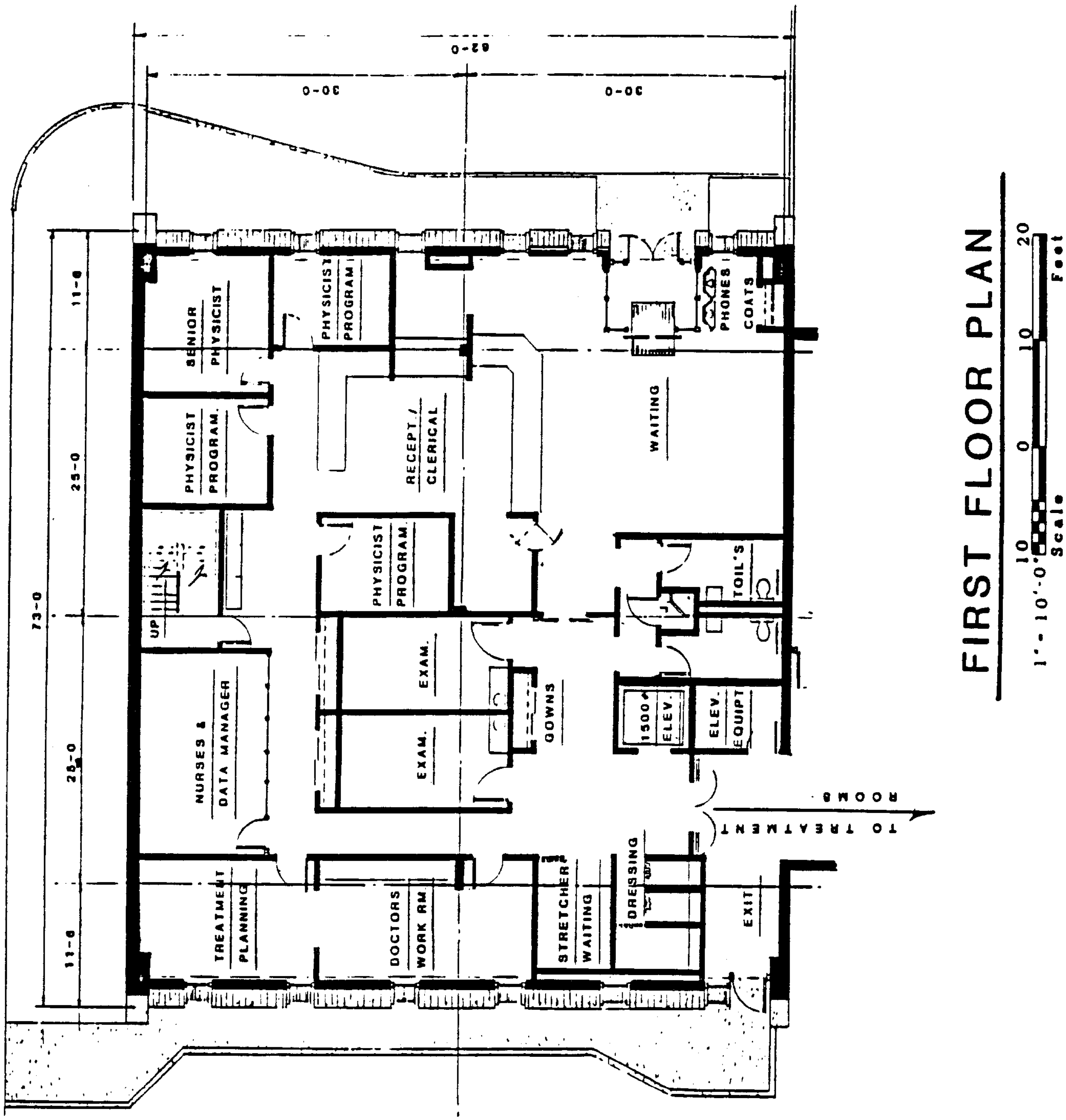
THE MEDICAL BUILDING

The type of building envisioned is one that will match the architectural style of the R. R. Wilson Hall and the accelerator building. A conceptual building exterior is shown on the cover of this report.

The proton beam lines and treatment rooms would be at ground level.

a. Work room (physicians, view boxes, CRT displays	350
b. Physicist/programmer offices (3 x 120 sq ft)	360
c. Waiting room (NTF has 180 sq ft)	400
d. Records, stationary, medical supplies storage	150
e. Electronics/dosimetry lab (elec. tech. desk)	250
f. Machine shop (drill press,sander, band saw,etc)	200
g. Treatment planning (2 desks for RTs)	150
h. Nurses/data manager (3 people)	250
i. Clerical/receptionist (3 people)	200
j. Examination rooms (2 x 150 sq ft)	300
k. Senior Physicist office	200
l. Computer room	450
m. Dressing rooms (2 x 15 sq ft)	30
n. Locker/lunch room	120
o. Mold room (dosimetrist desk)	150
p. Waiting room for stretcher patients	120
q. Visitor's office	120
Total Net Area (sq. ft.)	3800

THE MEDICAL BUILDING: FIRST FLOOR PLAN.



APPENDIX B11

CONSTRUCTION AND COMMISSIONING: COSTS.

The estimated costs of the subcomponents is given first in 1984 dollars. References to "Lines" refer to list of cost estimates given in Appendix B12.

After the costs of all subcomponents are given, adjustments are made to express the costs in 1985 dollars and include EDIA and contingency funds.

A. Plant. This includes the "bricks and mortar" for the beam enclosures, treatment rooms, radiation shielding, medical building, power supply room, site preparation and parking area for patients and staff. Line 14, M$ 1.08

B. Beam lines and nozzles. This covers all magnets, power supplies, vacuum, cooling water, cable trays, power cabling, closed circuit TV and intercoms, x-ray position verification systems, safety system and nozzles. This system will be able to carry proton clinical beams of two energies (70 and 203 MeV) to the treatment rooms, optimizing treatment of eyes and deeply seated malignancies. Lines 1+2+3+2x(4+5)+8+9+10, M$ 0.863

C. Treatment Rooms. This covers patient immobilization fixtures and capability to remotely adjust patient position. Line 2x6, M$ 0.642

D. Controls System. This system will control and/or monitor, as needed, all the beam lines, the nozzles, the equipment in the treatment rooms as well as control the dose delivered to the patient. Lines 2x7+11, M$ 0.317

E. Treatment Planning Computer. This computer will be a VAX/750 or VAX/785. This system would be essentially identical to the one in use at the Harvard Cyclotron Laboratory - Massachusetts General Hospital. Thus, a lot of manpower will be saved in using software already developed there and in exchanging future software (Appendix B13). Line 12, M$ 0.236

F. Tape Controlled Milling Machine. Depending on the actual treatment plan, each patient will need from one to four, perhaps even more, boluses to shape the distal part of the beam. The treatment planning computer will generate instructions for this tape controlled milling machine. Line 13, M$ 0.067

G. Examination Rooms, Equipment. This includes exam tables, exam chairs, mirrors, specula, stools, and miscellaneous tools. Line 15, M$ 0.024

H. Office and Waiting Room Type Equipment. Line 16, M$ 0.063

I. This includes a typical assortment of devices to carry out charged particle dosimetry as well as a Faraday cup for 203 MeV protons and an ultrasound scanner to permit cross checking the output from the CT scanners and measure eye sizes. Line 17, M$ 0.188

J. Operational Costs During Construction and Commissioning. This includes costs of personnel who will be hired to design specialized dosimetry, beam delivery and patient immobilization equipment, write application software for interpretation of dosimetry experiments, for dose delivery, and for treatment planning. In addition, they will cooperate in radiobiological experiments and participate in dosimetry intercomparisons with the Harvard Cyclotron Laboratory/Massachusetts General Hospital. It is hoped that this approach will allow completion of the commissioning of at least one treatment room within six months of completion of construction.

(a) List of personnel. Salaries include 25% of base salary as fringe benefits.

Calendar Year	1985		1986	1987
Operational Year	01		02	*1H03
Physician (PI)	0.1	k$ 13.	0.1	0.1
Physicist/programmers	4.0	300.	4.0	4.0
Electronics Techs	2.0	64.	2.0	2.0
Mechanical Tech	1.0	32.	1.0	1.0
Clerical	1.0	33.	1.0	1.0
Machinist	1.0	38.	1.0	1.0
Draftsman	1.0	31.	1.0	1.0
Mechanical Engineers	1.0	63.	1.0	1.0
Subtotal (in 1984 dollars)		k$ 574 M$ .574		
Subtotal (in 1985 dollars)		M$ .614		

* 1H03 means first half of year 03.

(b) All operational costs during construction and commissioning, in M$.

Calendar year	1985	1986	1987
Project Year	01	02	1H03*
a -salaries and fringes	0.614	0.657	0.352
b -beam time	-	-	0.358
c -supplies	0.026	0.027	0.015
d -travel	0.020	0.022	0.012
e -special equipment	0.032	0.034	0.018
Subtotal	0.692	0.740	0.755
f -overhead costs**(35% of a,c,d)	0.231	0.247	0.133
Subtotal (various dollars)	0.923	0.987	0.888
Subtotal (1985 dollars)	0.923	0.923	0.775

Total operational costs during construction and commissioning (1985 dollars), 0.923+0.923+0.775 = M$ 2.621.

Notes:
* 1H03 means first half of year 03.
** Overhead rates used in this calculation are consistent with Fermilab FY'84 experience. Substantial changes in the Fermilab rate for future years are not anticipated.

K. Resume of Construction Costs (1984 dollars).

a.	Plant		M$ 1.080
b.	Beam lines & 2 Nozzles		0.863
c.	2 Treatment Rooms		0.642
d.	Controls		0.317
e.	Treatment Planning Computer		0.236
f.	Tape Controlled Milling Machine		0.067
g.	Exam Room, Office, Shop Equipment		0.108
h.	Dosimetry Equipment		0.190
	Subtotal (1984 Dollars)		3.503
	Subtotal (1985 dollars)	(1.07)	3.748
i.	EDIA* (15% of plant)		0.173
j.	Operational costs* (1985 dollars)		2.621
	Subtotal		6.540
k.	25% Contingency		1.636
	Total (1985 dollars)		M$ 8.178

Note:
* Overhead rates used in this calculation are consistent with Fermilab FY'84 experience. Substantial changes in the Fermilab rate for future years are not anticipated. Furthermore, no allowance has been made for Full Cost Recovery as described in DOE Order 2100.

APPENDIX B12

COST BREAKDOWN PTF ELEMENTS

Total Cost Summary	Purchased Electronics	Software mods & development	Material Costs	Shop	Constr.		Assembly & Installation			Commissioning			Engineering	Drafting	TOTAL
					Welding	Material	Effort	Rigging	Alignment	Testing	Calibration	Electrical			
	$(k)	$(k)	$(k)	$(k)	$(k)	$(k)	$(k)	$(k)	$(k)	$(k)	$(k)	$(k)	$(k)	$(k)	$(k)
1 Additions to Linac Gallery Hardware			10	1		1	3					1	2	1	19
2 Prefocus Area Hardware			5	12		5	3	1		1			5	5	37
3 Front End Hardware			58	31	4	9	15	1	2				6	7	133
4 Beam Line Area Hardware 2@			16	3		5	7	1					2	2	37
5 Nozzle Room Hardware 2@			19	20	1	4	6	1	1	1	1		8	9	71
6 Treatment Room Hardware 2@	64		19	49		4	8		1			1	85	90	321
7 Local Control Room Hardware 2@	8		8				1			1		2	1		22
8 Systems (Water, Vacuum, Interlock, TV, PA)	51		82			11	11			4		30	10	10	209
9 Cable Trays			4									2			7
10 Power (Magnet & Disbtribution)			201				1	3		5		24	7	1	242
11 Control System	189		24	4		21	26			5		4			273
12 Treatment Planning Computer	231							1				3	1		236
13 Tape Controlled Milling Machine	20		45					1				1			67
14 Building, Enclosures															1080
15 Examination Room Equipment			20			2	1			1					24
16 Office, Waiting Room Equipment			60				3								63
17 Dosimetry Equipment			186				1			1					188

Cost and Effort Summary

	Purchased Electronics	Software mods & development	Material Costs	Constr.		Assembly & Installation			Commissioning			Electrical	Engineering	Drafting
				Shop	Welding	Material	Effort	Rigging	Alignment	Testing	Calibration			
	$(k)	M-D	$(k)	M-D	M-D	$(k)	M-D	M-D	M-D	M-D	M-D	M-D	M-D	M-D
1 Additions to Linac Gallery Hardware			10	3		1	24					4	8	12
2 Prefocus Area Hardware			5	57	2	5	22	1	3	4	1	1	25	43
3 Front End Hardware			58	149	17	9	114	2	13	1		1	32	61
4 Beam Line Area Hardware 2@			16	15	1	5	555	2	3	1		1	8	15
5 Nozzle Room Hardware 2@			19	95	3	4	48	1	6	8	11		39	79
6 Treatment Room Hardware 2@	64		19	236		4	58		5	1	3	3	433	831
7 Local Control Room Hardware 2@	8		8	1			6			8		8	5	2
8 Systems (Water, Vacuum, Interlock, TV, PA)	51		82		2	11	80		1	27		121	49	89
9 Cable Trays			4							2		8	2	4
10 Power (Magnet & Disbtribution)			201				5	5		34		95	37	5
11 Control System	189		24	18		21	192		2	36	1	15	1	2
12 Treatment Planning Computer	231							1				12	5	4
13 Tape Controlled Milling Machine	20		45				1	1		3		2	2	1
14 Building, Enclosures														
15 Examination Room Equipment			20			2	10			4				
16 Office, Waiting Room Equipment			60				20							
17 Dosimetry Equipment			140				5			10				

Cost Breakdown PTF Elements

	Purchased Electronics	Software mods & development	Material Costs	Shop	Constr.		Assembly & Installation			Commissioning			Engineering	Drafting
					Welding	Material	Effort	Rigging	Alignment	Testing	Calibration	Electrical		
	$(k)	M-D	$(k)	M-D	M-D	$(k)	M-D	M-D	M-D	M-D	M-D	M-D	M-D	M-D
1 Additions to Linac Gallery Hardware (1 needed)			9.5	3		.7	24		.4	.4		.4	8	12
1.1 Pulsed magnet														
1.1.1 Magnet modifications (none)														
1.1.2 Power supply (orig.)														
1.1.3 Vacuum chamber (orig.)														
1.2 Scattering foil at wall			0.5	3			1						3	2
1.3 Beam instrumentation														
1.3.1 Segmented SEM (H+V)			5.0				18		.2	.2		.2	5	10
1.3.2 Foil SEM			4.0			0.7	5		.2	.2		.2		
2 Prefocus Area Hardware (one needed)			5.4	56.5	2.1	4.5	22	1.25	2.5	4	.5	1	25	43
2.1 $\bar{p}$ cooling magnets (3 quads)														
2.1.1 Magnet modifications (none)														
2.1.2 Magnet stands			.3	1.5	.6		1		1				2	4
2.1.3 Power supplies (in 10.1.1)														
2.1.4 Vacuum chambers (orig.)														
2.2 Energy degrader														
2.2.1 Remotely controlled degrader			1.5	15		1.5	9		.25	1.			5	10

	Purchased Electronics	Software mods & development	Material Costs	Shop	Constr.		Assembly & Installation			Commissioning			Engineering	Drafting
					Welding	Material	Effort	Rigging	Alignment	Testing	Calibration	Electrical		
	$(k)	M-D	$(k)	M-D	M-D	$(k)	M-D	M-D	M-D	M-D	M-D	M-D	M-D	M-D
2.2.2 Stand			0.3	2	.5			.25	.25					1
2.3 Preliminary beam attenuator			3.3	38	1	1.0	11	.5	1	3	.5	1	18	28
2.4 Portable shielding						2.0	1	.5						
3 Front End Hardware (one needed)	.2		58.1	149	16.6	8.7	114	2	13.2	1.2		1.2	32	61
3.1 $\bar{p}$ cooling magnets (1 dipole + 7 quads)														
3.1.1 Magnet modifications (none)														
3.1.2 Magnet stands			.8	4	1.6		2		2					
3.1.3 Power supplies (in 10.1.1)														
3.1.4 Vacuum chambers (orig.)														
3.2 45° switch magnet														
3.2.1 Magnet construction			20	139	10								25	50
3.2.2 Magnet stand			.6	3	1			0.5	1				3	5
3.2.3 Power supply (in 10.1.2)														
3.2.4 Vacuum chamber			.7	3	1								2	4
3.3 Beam instrumentation														
3.3.1 Four segmented SEM			20.0				72		.8	.8		.8		
3.3.2 One foil SEM	.2		3.			.7	12		.2	.2		.2		

	Purchased Electronics	Software mods & development	Material Costs	Shop	Constr. Welding	Constr. Material	Assembly & Installation Effort	Assembly & Installation Rigging	Assembly & Installation Alignment	Commissioning Testing	Commissioning Calibration	Commissioning Electrical	Engineering	Drafting
	$(k)	M-D	$(k)	M-D	M-D	$(k)	M-D	M-D	M-D	M-D	M-D	M-D	M-D	M-D
3.4 Beam Dump														
3.4.1 One segmented SEM			5.				18		.2	.2		.2		
3.4.2 Dump structure			8.		3.		6	1					2	2
3.5 Portable shielding														
3.5.1 Between beam lines						8.0	4	.5						
4 Beam Line Area Hardware (2 needed)	.2		16.1	15	1.2	4.9	55.5	1.5	2.6	1.1		.6	8	15
4.1 $\bar{p}$ cooling magnets (6 Q)														
4.1.1 Magnet modifications (none)														
4.1.2 Magnet stands			.6	3	1.2		1.5		1.5					
4.1.3 Power supply (in 10.1.1)														
4.1.4 Vacuum chambers (orig.)														
4.2 Beam shutters			1.0	5		.1	2	.5		.5			5	10
4.3 Collimators			1.5	7		.1	2	.5	.5				3	5
4.4 Beam instrumentation														
4.4.1 Two segmented SEM			10.				36		.4	.4		.4		
4.4.2 One foil SEM	.2		3.			.7	12		.2	.2		.2		

	Purchased Electronics	Software mods & development	Material Costs	Shop	Constr. Welding	Constr. Material	Assembly & Installation Effort	Assembly & Installation Rigging	Assembly & Installation Alignment	Commissioning Testing	Commissioning Calibration	Commissioning Electrical	Engineering	Drafting
	$(k)	M-D	$(k)	M-D	M-D	$(k)	M-D	M-D	M-D	M-D	M-D	M-D	M-D	M-D
4.5 Portable shielding														
4.5.1 Around collimators						2.0	1	.5						
4.5.2 Between beam line area and nozzle area						2.0	1							
5 **Nozzle Room** Hardware (2 needed)			19.25	95	3.25	430	47.5	1.0	6.0	8.25	11.		39	79
5.1 Precollimator baffle			.5	4	.25		.5		.5				1	3
5.2 Safety Plug			.35	5		.05	5.0		.25	.25			3	7
5.3 1st scatter baffle			.3	2	.25	.03	.5		.5					1
5.4 Double scattering foil wheel			2.0	20		.3	7.0		1.75	2.0	2.0		7	15
5.5 2nd scatter baffle			.35	2	.25		.5		.5				1	2
5.6 Range shifter			.73	10		.94	6.0		.25	.5	3.0		3	6
5.7 Range chamber														
5.7.1 Range chamber body			1.03	5		.7	14.0		.25	2.0	4.		10	20
5.7.2 Range chamber holder			.46	7	.25	.28	2.0		.5		.5		4	10
5.8 Primary collimator														
5.8.1 H. collimator			1.55	18	.5	.9	5.0	.5	.5	1.5	.5		6	10
5.8.2 V. collimator			1.78	20	.5	.9	6.0		.5	1.5	.5		3	4

	Purchased Electronics	Software mods & development	Material Costs	Shop	Constr. Welding	Constr. Material	Assembly & Installation Effort	Assembly & Installation Rigging	Assembly & Installation Alignment	Commissioning Testing	Commissioning Calibration	Electrical	Engineering	Drafting
	$(k)	M-D	$(k)	M-D	M-D	$(k)	M-D	M-D	M-D	M-D	M-D	M-D	M-D	M-D
5.9 Nozzle Table			.2	2	1.25			.5	.5				1	1
5.10 Beam instrumentation														
5.10.1 Double multifoil SEM			10.			.2	1			0.5	.5			
6 Treatment Room Hardware (2 needed)	64.39		18.6	236		3.64	58		5	1	3	3.4	433	831
6.1 Wall slide assembly			2.5	36									125	250
6.1.1 Rails & basic support plate														
6.1.2 Eye snout assembly														
6.1.2.1 Basic assembly with X,Y motion														
6.1.2.2 Orifice plate holder														
6.1.2.3 CCTV visual monitor mount														
6.1.2.4 CCTF x-ray monitor mount														
6.1.2.5 Fixation light system														
6.1.2.6 Mask fixation system														
6.1.2.7 Misc.														
6.1.3 AVM snout assembly														
6.1.3.1 Basic assembly														
6.1.3.2 CCTV visual monitor mount														
6.1.3.3 CCTV multiple x-ray monitor mount														

Item	Purchased Electronics	Software mods & development	Material Costs	Shop	Constr.: Welding	Constr.: Material	Assembly & Installation: Effort	Assembly & Installation: Rigging	Assembly & Installation: Alignment	Commissioning: Testing	Commissioning: Calibration	Commissioning: Electrical	Engineering	Drafting
	$(k)	M-D	$(k)	M-D	M-D	$(k)	M-D	M-D	M-D	M-D	M-D	M-D	M-D	M-D
6.2 Head and neck chair			7.5	108									144	280
6.2.1 Chair base			2.5	36									19	30
6.2.1.1 Weight/torque support system														
6.2.1.2 Rotation system														
6.2.1.3 X-Y translation system														
6.2.1.4 Moving floor														
6.2.2 Chair (incl. 6.2.3)			5.0	72									125	250
6.2.2.1 Basic barber chair														
6.2.2.2 Basic chair modifications														
6.2.2.2.1 Angle & height of foot rest														
6.2.2.2.2 Height of chair														
6.2.2.2.3 Hydraulic system														
6.2.2.2.4 Arm rest height														
6.2.2.2.5 Mounting bracket for head fixation system														
6.2.2.2.5.1 Crank set up/down position														

	Purchased Electronics	Software mods & development	Material Costs	Shop	Constr. Welding	Constr. Material	Assembly & Installation Effort	Assembly & Installation Rigging	Assembly & Installation Alignment	Commissioning Testing	Commissioning Calibration	Commissioning Electrical	Engineering	Drafting
	$(k)	M-D	$(k)	M-D	M-D	$(k)	M-D	M-D	M-D	M-D	M-D	M-D	M-D	M-D
6.2.3 Head fixation system														
6.2.3.1 Chair attaching system														
6.2.3.2 Fixing plate with angle adjustment														
6.2.3.3 Adjustable bite block														
6.2.3.4 Adjustable ear plugs														
6.2.3.5 Reference plate fixation														
6.2.3.6 Reference plate														
6.2.3.6.1 Basic reference plate														
6.2.3.6.2 Bolus holder														
6.2.3.6.3 Orifice plate holder														
6.3 Patient Table			5.	72									144	280
6.3.1 Table base			2.5	36									19	30
6.3.1.1 Weight/torque support system														
6.3.1.2 Rotation system														
6.3.1.3 Moving floor and support														

	Purchased Electronics	Software mods & development	Material Costs	Shop	Constr. Welding	Constr. Material	Assembly & Installation Effort	Assembly & Installation Rigging	Assembly & Installation Alignment	Commissioning Testing	Commissioning Calibration	Commissioning Electrical	Engineering	Drafting
	$(k)	M-D	$(k)	M-D	M-D	$(k)	M-D	M-D	M-D	M-D	M-D	M-D	M-D	M-D
6.3.2 Table			2.5	36									125	250
6.3.2.1 Basic Table														
6.3.2.1.1 Table frame														
6.3.2.1.2 Tilt and dip adjustments														
6.3.2.1.3 X,Y adjustments														
6.3.2.1.4 Table top														
6.3.2.2 Table Fixtures														
6.3.2.2.1 Table end chair														
6.3.2.2.2 Bolus/orifice plate holder														
6.3.2.2.3 Kneeling board														
6.3.2.2.4 Bolus/orifice plate holder														
6.3.2.2.5 Up leg support														
6.3.2.2.6 Bolus/orifice plate holder														
6.3.2.2.7 Table extension														
6.3.2.2.8 Back holder														
6.4 X-ray systems	64		2.2	18		3.5	55		5	1	3		20	20
6.4.1 Chair position														
6.4.1.1 Ceiling mounted rail system														

	Purchased Electronics	Software mods & development	Material Costs	Shop	Constr.		Assembly & Installation			Commissioning			Engineering	Drafting
					Welding	Material	Effort	Rigging	Alignment	Testing	Calibration	Electrical		
	$(k)	M-D	$(k)	M-D	M-D	$(k)	M-D	M-D	M-D	M-D	M-D	M-D	M-D	M-D
6.4.1.2 Carriage and x-ray tube mounts														
6.4.1.3 Two x-ray tubes	*													
6.4.1.4 X-ray detector														
6.4.1.5 CCTV x-ray monitor (in 8.5.5)														
6.4.1.6 HV cabling to switch	*													
6.4.2 Table Position														
6.4.2.1 Axial x-ray tube position														
6.4.2.1.1 Wall mounted system														
6.4.2.1.2 Carriage and x-ray tube mount														
6.4.2.1.3 X-ray detector mount (on table)														
6.4.2.1.4 CCTV x-ray monitor (in 8.5.6)														
6.4.2.1.5 HV cabling to switch	*													
6.4.2.1.6 X-ray tube	*													
6.4.2.2 Overhead x-ray tube position														
6.4.2.2.1 Ceiling mounted tube														
6.4.2.2.2 X-ray detector mount (on table)														
6.4.2.2.3 CCTV x-ray monitor (in 8.5.8)														
6.4.2.2.4 HV cabling to switch	*													

	Purchased Electronics	Software mods & development	Material Costs	Shop	Constr. Welding	Constr. Material	Assembly & Installation Effort	Assembly & Installation Rigging	Assembly & Installation Alignment	Commissioning Testing	Commissioning Calibration	Electrical	Engineering	Drafting
	$(k)	M-D	$(k)	M-D	M-D	$(k)	M-D	M-D	M-D	M-D	M-D	M-D	M-D	M-D
6.4.2.2.5 X-ray tube	*													
6.4.2.3 Transverse x-ray tube position														
6.4.2.3.1 Wall mounted system														
6.4.2.3.2 Carriage and x-ray tube mount														
6.4.2.3.3 X-ray detector mount (same as 6.4.2.1.3)														
6.4.2.3.4 CCTV x-ray monitor (in 8.5.7)														
6.4.2.3.5 HV cabling to switch	*													
6.4.2.3.6 X-ray tube	*													
6.4.3 HV equipment														
6.4.3.1 One high voltage power supply	*64.								5	1	3			
6.4.3.2 Four HV switches/control unit	*													
6.4.3.3 X-ray detectors (plate holders, etc)			1.6											
6.4.3.4 Film safe			.6				1							
6.5 Miscellaneous equipment	.39		1.4	2		.14	3					3.4		1
6.5.1 Illuminated viewing box (6)			1.2									3		
6.5.2 Sink with H/C water (in civil constr.)														
6.5.3 Patient controlled beam off switch			.1			.1	2					.2		1

	Purchased Electronics	Software mods & development	Material Costs	Shop	Constr. Welding	Constr. Material	Assembly & Installation Effort	Rigging	Alignment	Commissioning Testing	Calibration	Electrical	Engineering	Drafting
	$(k)	M-D	$(k)	M-D	M-D	$(k)	M-D	M-D	M-D	M-D	M-D	M-D	M-D	M-D
6.5.4 TV monitor - 25" repeater from IBM-PC	.39		.1	2		.04	1					.2		
7 Local Control Room Hardware (2 needed)	7.9		8.44	1		.18	5.5			7.9		8	5	2
7.1 IBM PC with floppy & hard disk, monitor, printer	6.0		.1			.1	3			1				
7.2 Six monitors + 1 TV	1.9		0.1	0.5			0.5			0.5				
7.3 Thumbwheel entry for dose overrun			.22	.25		.04	1			.2				
7.4 Thumbwheel entry for time overrun			.22	.25		.04	1			.2				
7.5 Illuminated viewing box (4)			.8									2		
7.6 Beam line enable switch			1.5							1.5		2	2	1
7.7 Beam initiate switch			1.5							1.5		2		
7.8 Activate x-ray tube of choice (in 6.4.3.1)														
7.9 Emergency off button (in 8.8)														
7.10 X-ray tube safety switch			4.0							3		2	3	1
8 Systems (water, vacuum, interlock, TV, PA)	51.43		81.5		2	10.6	80		.75	27.25		121	49	89
8.1 Water system			31.5				37					69	22	26
8.1.1 Water pumping station			17.5				37					20	15	20
8.1.2 Distributed header system for magnets and collimators.			10									36	4	3

	Purchased Electronics	Software mods & development	Material Costs	Shop	Constr. Welding	Constr. Material	Assembly & Installation Effort	Assembly & Installation Rigging	Assembly & Installation Alignment	Commissioning Testing	Commissioning Calibration	Commissioning Electrical	Engineering	Drafting
	$(k)	M-D	$(k)	M-D	M-D	$(k)	M-D	M-D	M-D	M-D	M-D	M-D	M-D	M-D
8.1.3 Extend chilled water lines			4									13	3	3
8.2 Vacuum system	7.2		38.2		2	.6	11			14			14	47
8.2.1 Connections between magnets			14.2		2		5			5			4	7
8.2.2 Pumps for entire system-Linac hall to nozzle room	6		24							5				
8.2.3 Vacuum readout	1.2					.6	6			4				
8.2.4 System Design													10	40
8.3 Radiation interlock system	10		4			10	7			10		50	4	5
8.4 Personnel interlock system (in 8.3)														
8.5 TV monitoring system (2 needed)	30.8		2.3				8		.75	2.		2	2	4
8.5.1 Eye CCTV visual monitor	.25						.25		.25					
8.5.2 Eye CCTV x-ray monitor + lens	2.2						.25							
8.5.3 AVM CCTV visual monitor	.25						.25		.25					
8.5.4 AVM CCTV x-ray monitor + lens	2.2						.25							
8.5.5 Head transverse CCTV x-ray monitor +lens	2.2						.25							
8.5.6 Table axial CCTV x-ray monitor + lens	2.2						.25							
8.5.7 Table transverse CCTV x-ray monitor + lens	2.2						.25							
8.5.8 Table overhead CCTV x-ray monitor (same as 8.5.7)							.25							

	Purchased Electronics	Software mods & development	Material Costs	Shop	Constr.		Assembly & Installation			Commissioning			Engineering	Drafting
					Welding	Material	Effort	Rigging	Alignment	Testing	Calibration	Electrical		
	$(k)	M-D	$(k)	M-D	M-D	$(k)	M-D	M-D	M-D	M-D	M-D	M-D	M-D	M-D
8.5.9 Two high resolution room monitors	.70						1.0							
8.5.10 Two remote control zoom, pan, tilt	3.2						.5		.25					
8.5.11 Two close-up lenses	.20													
8.5.12 Frame grabber	6.5						0.5			1.0				
8.5.13 Coadder & display computer (IBM-PC)	7.5						0.5			1.0				
8.5.14 Six video channel selectors	1.2						0.5							
8.5.15 Video cabling + terminations			2.3				3.0				2			
8.6 PA system (1 needed)	3.43		.5				7.0			1.25		2	2	4
8.6.1 Speakers & mikes in treatment room	.66						1.0			.25				
8.6.2 Speakers & mikes in beam & P.S. Area	1.35						2.0			.25				
8.6.3 Speakers, mike, headset at control room	.42						1.0			.25				
8.6.4 Amplifiers and selector switchs	1.0						1.0			.5				
8.6.5 Cabling			.5				2.0					2		
8.7 Fire alarm system (in civil construction)														
8.8 Emergency power off system			5				10					8	5	3
8.8.1 Fast disconnect at "mains" (in 10.3)														
8.8.2 Push button system in PS room														
8.8.3 Cord pull system in beam line/nozzle areas														

	Purchased Electronics	Software mods & development	Material Costs	Constr.: Shop	Constr.: Welding	Constr.: Material	Assembly & Installation: Effort	Assembly & Installation: Rigging	Assembly & Installation: Alignment	Commissioning: Testing	Commissioning: Calibration	Electrical	Engineering	Drafting
	$(k)	M-D	$(k)	M-D	M-D	$(k)	M-D	M-D	M-D	M-D	M-D	M-D	M-D	M-D
8.8.4 Push buttons in treatment room														
8.8.5 Push buttons at control console (in 7.9)														
9 Cable Trays			3.5							2		8	2	4
9.1 Magnet power trays from PS area to prefocus area, front end and beam line areas			1.7							1		4	1	2
9.2 Signal trays connecting all areas and control rooms. Main signal junctions at PS room and cross walk at QD5			1.8							1		4	1	2
10 Power			201.4				5	5		34		95.4	37	5
10.1 Power supplies														
10.1.1 For $\bar{p}$ cooling magnets (17 new P.S.@550A)			80.				3			17		17	10	
10.1.2 For 45^{o} switch magnet (3000 A)			80.				2	5		10		2	20	
10.2 Cables to magnets														
10.2.1 For $\bar{p}$ cooling magnets			11.							1		14.4	1	
10.2.2 For 45^{o} switch magnets			1.4							1		2	1	
10.3 Power Distribution (free substation)			29.							5		60	5	5

	Purchased Electronics	Software mods & development	Material Costs	Constr.		Assembly & Installation			Commissioning					
				Shop	Welding	Material	Effort	Rigging	Alignment	Testing	Calibration	Electrical	Engineering	Drafting
	$(k)	M-D	$(k)	M-D	M-D	$(k)	M-D	M-D	M-D	M-D	M-D	M-D	M-D	M-D
11 Control System	189.15		23.97	18		20.69	191.7		1.5	36.	1	14.75	1	2
11.1 ETHER net connection	2.5													
11.2 ETHER net - ARC net bridge	1.4													
11.3 ARC net system			6.15				6					5		
11.3.1 ARC net hub			0.2				3							
11.3.2 ARC net distribution			0.25									1		
11.3.3 ARC net station racks			5.7				3					4		
11.4 ARC net stations	185.25		17.82	18		20.69	185.7		1.5	36.	1	9.75	1	2
11.4.1 200 MeV area	13.29		0.5			.2	3			1				
11.4.1.1 ARC net station	3.8		0.5				2							
11.4.1.2 CAMAC - ARC net														
11.4.1.2.1 CAMAC - ARC net connections	1.27													
11.4.1.2.2 CAMAC crate/PS/controller/timing	4.22													
11.4.1.3 Inputs														
11.4.1.3.1 Foil SEM	*													
11.4.1.3.2 Segmented SEM	* 4.0					.2	1			1				
11.4.1.3.3 All information $\bar{p}$ had in CAMAC	0.0													

	Purchased Electronics	Software mods & development	Material Costs	Shop	Constr. Welding	Constr. Material	Assembly & Installation Effort	Assembly & Installation Rigging	Assembly & Installation Alignment	Commissioning Testing	Commissioning Calibration	Commissioning Electrical	Engineering	Drafting
	$(k)	M-D	$(k)	M-D	M-D	$(k)	M-D	M-D	M-D	M-D	M-D	M-D	M-D	M-D
11.4.2 Power supply area	38.57		6.64			6.39	28		1	9.5		7.5		
11.4.2.1 ARC net station	3.8		0.5				1							
11.4.2.2 CAMAC - ARC net	5.49						2							
11.4.2.2.1 CAMAC - ARC net connection	1.27						1							
11.4.2.2.2 CAMAC crate/PS/controller/timing	4.22						1							
11.4.2.3 Inputs	26.58		6.04			5.7	22		1	7.5		6		
11.4.2.3.1 Foil SEM (input in 11.4.3.3.1.1)	0.0													
11.4.2.3.2 Four segmented SEM	16.0		0.2				1			1				
11.4.2.3.3 Magnet currents actual (ADC) (18)	1.4					.35	3			1		.5		
11.4.2.3.4 Energy degrader position	x .5		.22			.1	2			1		.5		
11.4.2.3.5 Power supply status (18)	1.5		1.68			2.0	4			2		1		
11.4.2.3.6 Water station status	x		.14			.17	1			.5		.5		
11.4.2.3.7 Water temp via TV	.25		.1			.15	.5					.5		
11.4.2.3.8 Water flow via TV	.25		.1			.15	.5					.5		
11.4.2.3.9 Beam shutter position (2)	x		.14			.1	.5					.25		

	Purchased Electronics	Software mods & development	Material Costs	Shop	Constr. Welding	Constr. Material	Assembly & Installation Effort	Assembly & Installation Rigging	Assembly & Installation Alignment	Commissioning Testing	Commissioning Calibration	Commissioning Electrical	Engineering	Drafting
	$(k)	M-D	$(k)	M-D	M-D	$(k)	M-D	M-D	M-D	M-D	M-D	M-D	M-D	M-D
11.4.2.3.10 Collimator temperature (2)	x		.16			.1	.5					.25		
11.4.2.3.11 Beam loss monitors (12)	3.8		3.3			1.56	6		1	1		1		
11.4.2.3.12 Vacuum readings (8)	2.88					1.02	3			1		1		
11.4.2.4 Outputs	2.7		.1			.69	3			2		1.5		
11.4.2.4.1 Magnet currents (18)	2.5					.40	1			1		.5		
11.4.2.4.2 Energy degrader position	x+.1		.1			.13	1			.5		.5		
11.4.2.4.3 Activate PS (18) (in 11.4.2.3.6)														
11.4.2.4.4 Activate water station														
11.4.2.4.5 Beam shutter position (2)	x+.1					.16	1			.5		.5		
11.4.2.4.6 Set times to 5 SEM														
11.4.3 Nozzle/treatment area	131.89		10.68	18		14	153.8		.5	25	1	2.25	1	2
11.4.3.1 ARC net station	3.8		.5				1							
11.4.3.2 CAMAC - ARC net	11.09						2							
11.4.3.2.1 CAMAC - ARC net connection	1.64						1							
11.4.3.2.2 CAMAC crates/PS/controller/timing	9.36						1							
11.4.3.3 Inputs	71.51		10.12	18		9.1	116.8		.5	14	1	2.25	1	2
11.4.3.3.1 Beam areas	20.4		1.5			3.28	5		.5	2.5		.5		
11.4.3.3.1.1 Two foil SEM	2.5		.2			.2	1			.5				

	Purchased Electronics	Software mods & development	Material Costs	Shop	Constr.		Assembly & Installation			Commissioning			Engineering	Drafting
					Welding	Material	Effort	Rigging	Alignment	Testing	Calibration	Electrical		
	$(k)	M-D	$(k)	M-D	M-D	$(k)	M-D	M-D	M-D	M-D	M-D	M-D	M-D	M-D
11.4.3.3.1.2 Four segmented SEM	16.5					2.8	2			1.5				
11.4.3.3.1.3 Four beam loss monitors	1.4		1.3			.28	2		.5	.5		5		
11.4.3.3.2 Nozzle areas	22.51		2.17			1.77	16			3	1	1.75	1	2
11.4.3.3.2.1 56 "microswitch positions"	1.2		1.12			.2	3			1		1		
11.4.3.3.2.2 Six encoders (includes encoders)	5.66		.3	10		.78	4			1		.5	1	2
11.4.3.3.2.3 120 Channels of ADC	14.4					.59						.25		
11.4.3.3.2.4 Two HV PS	.4					.1								
11.4.3.3.2.5 Two gas flows	.25		.25			.1	1							
11.4.3.3.2.6 Two double foil SEM (dual record system)	0.6		0.5				8			1	1			
11.4.3.3.3 Treatment Rooms	28.6		6.45	18		4.05	95.8			8.5				
11.4.3.3.3.1 1553 RT stations	1.04		2.4			.8	22			2				
11.4.3.3.3.2 Eye-AVM assembly														
11.4.3.3.3.2.1 Eight snout position indicators	.1		.19			.04	1.4			.2				
11.4.3.3.3.2.2 Two fixation light position indicators	1.62		.16	1		.19	3.1			.5				
11.4.3.3.3.2.3 Four mask position (2X,2Y)	3.04		.29	2		.14	4.3			.5				
11.4.3.3.3.2.4 Two orifice plate ID			.1			.16	2.9			.2				

	Purchased Electronics	Software mods & development	Material Costs	Shop	Constr. Welding	Constr. Material	Assembly & Installation Effort	Assembly & Installation Rigging	Assembly & Installation Alignment	Commissioning Testing	Commissioning Calibration	Electrical	Engineering	Drafting
	$(k)	M-D	$(k)	M-D	M-D	$(k)	M-D	M-D	M-D	M-D	M-D	M-D	M-D	M-D
11.4.3.3.3.2.5 Two mask ID			.1			.16	2.9			.2				
11.4.3.3.3.3 Chair system														
11.4.3.3.3.3.1 Two chair height	1.52		.16	1		.1	2.7			.2				
11.4.3.3.3.3.2 Two back angle	1.52		.14	1		.06	2.1			.2				
11.4.3.3.3.3.3 Two plate tilt	1.52		.14	1		.06	2.1			.2				
11.4.3.3.3.3.4 Two plate height	1.52		.14	1		.09	2.5			.2				
11.4.3.3.3.3.5 Two chair base rotation angle	1.52		.16	1		.09	2.5			.2				
11.4.3.3.3.3.6 Four platform positioner (2X,2Y)	3.04		.33	2		.2	5.4			.4				
11.4.3.3.3.3.7 Two bolus ID			.10			.16	2.6			.2				
11.4.3.3.3.3.8 Two orifice ID			.10			.16	2.6			.2				
11.4.3.3.3.4 Table system														
11.4.3.3.3.4.1 Two base rotation angle	1.52		.16	1		.09	2.6			.2				
11.4.3.3.3.4.2 Four table position (2X,2Y)	3.04		.46	2		.40	8.8			.4				
11.4.3.3.3.4.3 Two table longitudinal position	1.52		.16	1		.09	2.6			.2				
11.4.3.3.3.4.4 Two end fixture height	1.52		.16	1		.10	2.8			.2				
11.4.3.3.3.4.5 Six jack heights	4.56		.49	3		.30	8.2			.4				

	Purchased Electronics	Software mods & development	Material Costs	Constr.		Assembly & Installation				Commissioning				
				Shop	Welding	Material	Effort	Rigging	Alignment	Testing	Calibration	Electrical	Engineering	Drafting
	$(k)	M-D	$(k)	M-D	M-D	$(k)	M-D	M-D	M-D	M-D	M-D	M-D	M-D	M-D
11.4.3.3.3.4.6 Four bolus ID			.21			.32	5.5			.6				
11.4.3.3.3.4.7 Four orifice ID			.21			.32	5.5			.6				
11.4.3.3.3.5 X-ray system														
11.4.3.3.3.5.1 Four position indicators chair station unit			.09			.02	.7			.5				
11.4.3.4 Outputs	45.58		.06			4.9	34			11				
11.4.3.4.1 Beam areas														
11.4.3.4.1.1 Set times on six SEM														
11.4.3.4.2 Nozzle area														
11.4.3.4.2.1 Twenty solenoid pulls	.38		.06			.1	2			1				
11.4.3.4.2.2 Six motor drives	7.2					.9	6			2				
11.4.3.4.2.3 Two HV														
11.4.3.4.2.4 Timing signals for 2 range chambers														
11.4.3.4.2.5 Set times for 2 double SEM														
11.4.3.4.3 Treatment Room														
11.4.3.4.3.1 Eye-AVM assembly														
11.4.3.4.3.1.1 Two fixation light position	2.0					.3	2			.6				

				Constr.		Assembly & Installation			Commissioning					
	Purchased Electronics	Software mods & development	Material Costs	Shop	Welding	Material	Effort	Rigging	Alignment	Testing	Calibration	Electrical	Engineering	Drafting
	$(k)	M-D	$(k)	M-D	M-D	$(k)	M-D	M-D	M-D	M-D	M-D	M-D	M-D	M-D
11.4.3.4.3.2 Chair system														
11.4.3.4.3.2.1 Two base rotation motor drives	3.6					.3	2			.6				
11.4.3.4.3.2.2 Four base X,Y motors	7.2					.6	4			1.2				
11.4.3.4.3.2.3 Four mask (2X,2Y) motors	4.8					.6	4			1.2				
11.4.3.4.3.3 Table system														
11.4.3.4.3.3.1 Two base rotation motor drives	3.6					.3	2			.6				
11.4.3.4.3.3.2 Four table position (2X,2Y) motor drives	7.2					.6	4			1.2				
11.4.3.4.3.3.3 Six motors for jack heights	7.2					.9	6			2				
11.4.3.4.3.3.4 Two end fixture height motors	2.4					.3	2			.6				
11.4.3.4.3.4 X-Ray system														
11.4.3.4.3.4.1 Misc (nothing at present)														
11.4.4 Local control room (2 needed)	1.5					.1	.9			.5				
11.4.4.1 IBM PC station (floppy + hard disc + printer + monitor, in 7.1)														
11.4.4.2 IBM - ARC net connection	.5					.1	.5			.5				
11.4.4.3 Inputs														

	Purchased Electronics	Software mods & development	Material Costs	Shop	Constr. Welding	Constr. Material	Assembly & Installation Effort	Assembly & Installation Rigging	Assembly & Installation Alignment	Commissioning Testing	Commissioning Calibration	Electrical	Engineering	Drafting
	$(k)	M-D	$(k)	M-D	M-D	$(k)	M-D	M-D	M-D	M-D	M-D	M-D	M-D	M-D
11.4.4.3.1 Thumbwheel entry for dose overrun (see 7.3)	.5						.2							
11.4.4.3.2 Thumbwheel entry for time overrun (see 7.4)	.5						.2							
11.4.4.3.3 Beam line enable key switch (in 8.4)														
11.4.4.3.4 Beam activate key switch (in 8.4)														
11.4.4.3.5 Treatment plan via floppy disc														
11.4.4.4 Outputs														
11.4.4.4.1 Misc (nothing at present)														
12 Treatment Planning Computer (duplicating Harvard VAX 750 system)	231							1				12	5	4
13 Tape Controlled Milling Machine	20		45				1	1		3		2	2	1
14 Building, Enclosures														
15 Examination Room Equipment			20			2	10			4				
16 Office, Waiting Room Equipment			60				20							
17 Dosimetry Equipment			80				5			10				

Appendix B13: Commercial equipment

APPENDIX B13

EQUIPMENT COMMERCIALLY AVAILABLE: COSTS

A. Computer for Treatment Planning.

The Fermilab CDC Cyber 175 computer will not be able to support 3-D treatment planning and display without additional hardware (not planned at present) and extensive software rewriting. Both HCL-MGH and LBL programs are presently on VAX systems and software trannsfer would be relatively simple. This would save money in the long run since the overall programming effort would be smaller.

1 - VAX/750, Floating Point Unit, 2 megabytes of memory,	
1 - RM80 disk (124 megabytes), 1-RP07 disk (600 megabytes),	
1 - TU77 tape drive, 1600 BPI, 8 terminal ports, console, without software, with 15% discount ($161,755).	
Lexidata 3400 display processors, -	
1 - 640x512x16 and	
1 - 640x512x10 ($61,800).	
1 - Printronix 600 m printer ($6,000).	
2 - LSI ADM-3a terminals ($1,000).	231.0
Installation	3.0
Subtotal k$	234.0

B. Dosimetry Equipment.

	k$
4 - Exradin 0.05 cc I Ch @ 700 each	3.0
2 - Keithley Electrometer #616 @ 2770	5.5
2 - Variable PS $\pm$3000 V, Fluke 415B @ 2095	4.5
1 - 4-1/2 digit $\overline{\text{D}}$VM Keithley 173A	1.0
1 - Tektronix Model #465B Oscilloscope	4.0
2 - Parallel plate ionization chambers for field measurement	2.4
5 - 90 Sr sources to check stability of ion chambers (@ 30 mCi, 700 each)	3.5
1 - Densitometer	1.5
2 - Thermocouple reader (6 or more inputs, computer selectable	1.5
1 - Digital barometer Barocell Model #1174	2.5
1 - NaI coincidence system	9.5
1 - TLD reader, Harshaw #3000-A	5.0
1 - Faraday cup and power supply	20.0
1 - X-Y-Z Positioner	18.0
1 - Proton radioequivalent Rando phantom	8.0
1 - Los Alamos-type phantoms	3.0
1 - Ultrasound scanner	80.0
Miscellaneous & testing	17.1
Subtotal k$	190.0

Appendix B13: Commercial equipment

C. Examination Room Equipment (2 rooms).

	k$
2 - ENT exam chairs at 1500 each	3.0
2 - Gyne table at 1500 each	3.0
2 - Exam tool table	1.0
2 - X-ray storage cart	1.0
1 - Autoclave	1.0
2 - Sphygomamanometers	.4
2 - Otoscopes	.4
2 - Ophthalmoscopes	.6
2 - Exam stools	.2
2 - Exam lights	1.0
2 - Table lights	.3
2 - Tool tables	.4
2 - Four-fold x-ray view boxes	.7
2 - Storage cabines with doors and drawers	3.0
Miscellaneous	4.0
Subtotal k$	20.0

D. Office and Waiting Room Equipment.

	k$
18 - Desk, 30x60, 6 drawer at 425 each	7.7
2 - Secretary work center at 500	1.0
36 - Chairs (arm chairs with casters) at 250	9.0
2 - Secretarial chairs at 190	.4
20 - Tables, 30x60 at 150	3.0
1 - Large table, 36x72	.5
1 - Conference table, 48x120	1.0
14 - Conference chairs at 160	2.0
20 - Filing cabinets, 5 drawer, 28.5 deep at 250	5.0
12 - Storage cabinets, 2 door at 220	2.6
12 - Staff lockers 72-12-18 at 100	1.2
12 - Dressing room lockers 36x12x18 at 100	1.2
4 - Coat racks at 140	.6
4 - Stools, work bench at 120	.5
16 - Waiting room chairs (with center table) at 500	8.0
18 - Bookcases 78" high at 150	2.7
4 - X-ray storage cabinet	2.8
4 - Sony dictaphones at 300	1.2
2 - IBM Selectric III typewriters at 800	1.6
9 - LSI ADM-3a terminals & modems at 1500	13.5
Miscellaneous	10.0
Subtotal k$	75.5

E. Shops

Miscellaneous hand tools and small power tools for electronics, mold room and shop — k$ 12.0

F. Subtotal for
Exam room, office and shop equipment (20+76+12) — k$ 108.0