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THE UNIVERSITY OF NEW MEXICO

DATE: October 22, 1976

TO: Al Smith
Jim Bradbury
FROM: Ken Hogstrom KH

SUBJECT: November 21, 1976 Patient Treatment

The purpose of this memo is to convey between members of the Biomedical group, both MP-3 and UNM/CRTC, some of the progress and remaining tasks which will be required for a successful patient treatment cycle beginning November 21, 1976.

A. New Beam Development

By the end of Cycle 9 three new treatment beams had been developed; a broad low, medium, and high momentum beam, which are referred to as tunes 18, 13, and 17 respectively. Each tune can be manually set from the button panel, with the exception of tune 17, for which one must manually raise the bending magnets above their cycling points. Each tune presently uses the good wedge with identical slit settings. Beam parameters for the three beams are listed at the end of this memo.

Howard Amols has constructed range shifter functions for 5 cm and 8 cm biologically flat widths which supplement the ≈ 2 cm width for "range shifter static". Physical descriptions of these beams are given at the end of this memo.

Because of the 27 cm penetration of the high momentum beam, the QTD (effective edge of final quadruple to tumor distance) will be changed from 90 cm to 105 cm for all future treatment beams which do not use the brass collimators. The brass collimators will remain with the 90 cm QTD.

Progress has been made for understanding bolus. Earlier results with paraffin bolus for teflon inhomogeneity indicated that bolus was not adequately correcting the dose. Since then a program has been written that accurately calculates the stopping power of teflon (1.81) and paraffin (.928). Results show that approximately 1.5 gm/cm^2 too much paraffin bolus was used for the teflon experiments. These errors had little effect on the bolus correcting for an air inhomogeneity and the results of these measurements are given at the end of this memo.

One last problem had to do with collimation. The high momentum beam required 6 cm thick collimators, and the slope of the aperture in the collimator strongly influenced the entrance dose. The depth dose for an 11 x 9 x 3 collimator placed immediately above a 10 x 8 x 3 collimator is compared to that from a 10 x 8 x 6 collimator. In lieu of these results, three dosimetry shifts will be devoted to the problem of collimation next cycle.

B. Treatment Planning

From the physicist's point of view, treatment planning is calculating dose distributions for specific treatment conditions which

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might be used for treating a prescribed volume. The beam tune, bolus, collimator and range shifter function which best match the dose distribution prescribed by the radiotherapist will be selected. Results of treatment planning will then be given to the radiotherapist for approval.

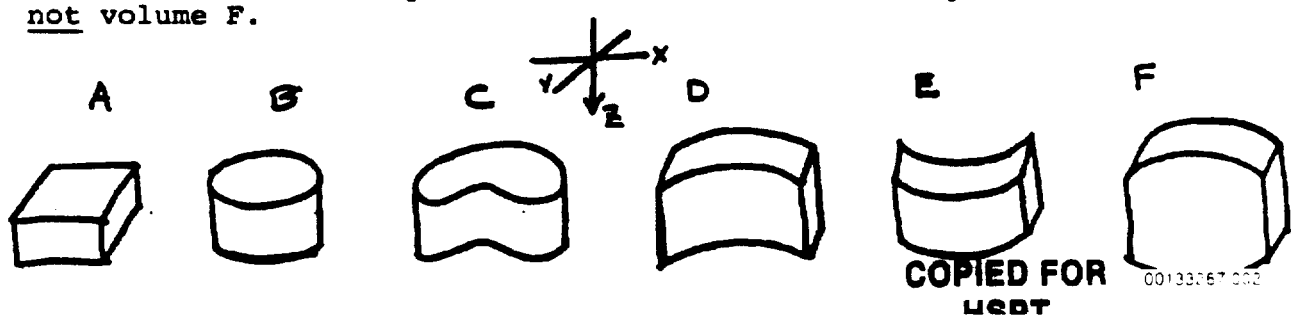
It is understood by UNM/CRTC that Pete Berardo's program PIPLAN will do the treatment planning pending successful comparisons to the measured dosimetry data supplied by the UNM/CRTC personnel. Certain input parameters must be provided by the radiotherapist:

1. a precise definition of the treatment volume, especially concerning size, dose, flatness and dose falloff;
2. whether single or multiple ports are desired;
3. any preferred direction for the treatment port or ports;
4. any vital organs to which the dose need be held to a specified minimum;
5. anatomical cross-sections which indicate density of inhomogeneities in all regions of interest;
6. whether or not bolus is desired to correct for inhomogeneities; and
7. if bolus is desired, whether or not it is desired directly on the patient or how far off the patient it is required (from a calculational and physical point of view, compactness of patient, bolus, collimator, and range shifter with a minimum of air gaps yields the best results).

Collimation will be performed by approximately 3 cm thick Cerrobend collimators for the low and medium momentum beams and approximately 6 cm thick Cerrobend collimators for the high momentum beam. The high stopping power (5.13) and molding characteristics of the Cerrobend justify its use.

The collimator and bolus will be presently determined by the parallel ray method using paraffin as bolus material, although a more sophisticated method is a high priority, future upgrade for PIPLAN. Paraffin has been selected because its stopping power (.928) is near that of muscle (.992) and because of its molding characteristics.

Concerning the use of collimation and bolus, it is important to realize the types of uniform dose volumes which can be achieved by individual ports. If the beam is incident in the +Z direction, then the range shifter controls the Z dimension of the beam with the constraint that the thickness in Z of the volume is constant at any point in the (X,Y) plane. Collimation, on the other hand, allows the (X,Y) cross-section of the volume to be shaped in an arbitrary manner within the region of the incident beam. These two constraints allow the volumes A, B, and C in the figures below. By using bolus, these volumes can be shaped in Z, but the constraints above still hold. This allows, for example, volumes D and E in the figure below, but <u>not</u> volume F.



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C. Beam Hardware

There are seven components which will be considered to be part of the beam hardware. Changes in these standard operations will now be discussed:

1. Target - a new target is being installed for the October 31 run cycle; the old target had a crack. This could explain the decrease in dose rate/uA observed during the past run cycle.

2. Magnets - the magnets have now been successfully run several hours at the high momentum beam's high current settings. Jim Bradbury feels that this is an indication that these magnet settings can safely be used for patient treatment. On this basis the UNM/CRTC understands that the high momentum beam is available for patient treatment.

Richard Kittell issued an October 8 memo stating that the Biomed triplet (QM01, QM02, and QM03) have had their cycling currents reduced from over 700A to 400A. Mike Paciotti believes that this will have no effect on the channel optics.

3. Wedges - Jim Bradbury has stated that the automatic wedge changer (AWC) will be installed by November 15, 1976. For patient treatment the good wedge, poor wedge, and an undetermined wedge should be the three wedges installed in the AWC. This will allow the use of not only setups from the previous treatment cycle, but also for the low, medium, and high momentum beams.

4. Slits - manual slit controls have been installed on the control panel. Will their output be connected to a DVM, and if so, will there be a way of manually and accurately setting the slits in case of computer failure? There was also some problem last cycle with the CAMAC controller for the slits. Are there spare controllers now available?

5. Range shifter - Don Liska and John Somers modified the manual control for moving the range shifter. There is now a safety brake on the range shifter so that one can move the range shifter up/down only by releasing the brake and applying hydraulic power simultaneously. This modification was to insure patient safety under the range shifter.

During treatment the range shifter will be run by the microprocessor or in some cases by the computer. Software needs to be written to check the range shifter operation; this will be discussed later.

Two modifications are still needed before the range shifter is suited for patient treatment. First, a method for recording the range shifter position relative to the 105 cm QTD is required. Ken Hogstrom and John Somers will take care of that. Second, the lock on the range shifter needs to be corrected so that the range shifter locks into position coaxial with the beam center (Z axis). It is presently off-center about 1.5 cm. Don Liska and John Somers have been notified and are correcting this problem.

6. Collimators - Cerrobend collimators are presently planned to be supported by the patient support assembly. The standard collimator size is 24 x 22 x 3 or 6, which for Cerrobend means maximum weights of 35 or 70 lbs. This weight could be a rather stringent requirement for the patient support structure. There may be a need for an independent collimator support. Dick Lane has pointed out that such a device could provide primary collimation above the patient for head and neck cases where the patient collimator would have to be

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small.

Consequently, it is planned that the Biomed dosimetry lab will build a collimation support assembly to be attached to the treatment couch.

7. Bolus - bolus will be paraffin wax and will be constructed by the Biomed dosimetry lab as discussed in the previous section.

8. Patient alignment - because there will be no collimator precisely fixed to the beam channel for treatment of large volumes, as is the case for the brass collimators, laser alignment will be required. A pair of overhead lasers will define the XZ and YZ planes. Their intersection will define the Z axis. This will allow the physician to orient the patient, collimator, and bolus properly in the XY plane. A pointer which measures QSD (quadrupole skin distance) will allow the physician to align the patient to the proper height so that the far edge of the tumor will be at the 105 cm QTD. There will also be two lasers shooting lines at a QTD of 105 cm in the XY plane which will intersect at X = Y = Z = 0. These lasers will assist in confirming patient alignment.

D. Computer Software Development

Below is a list of software developments which can hopefully be implemented prior to the November 21 patient treatment cycle:

1. Computer setting of beam tunes - it is understood by UNM/CRTC that Richard Kittell's program will set the magnets, slits and correct wedge for each patient tune and that the feedback for each setting will be checked against an input file. This setup procedure should include the ability to set up the high momentum tune without having to manually raise the magnet currents.

2. Range shifter monitoring - there should be periodic checks by the computer that the microprocessor commands are being followed by the range shifter by checking the feedback from the shaft encoders. Likewise the range shifter function selected by the microprocessor should be checked by the computer against a computer file of the desired range shifter function both before and after patient treatment.

Don Liska and Jim Halbig have come up with a quick scheme for making new memory chips for new range shifter functions at the Biomed Facility during patient treatment.

3. Gas pressure monitoring - there should be a button panel program that dumps gas pressures to the DECwriter so that proper helium and argon pressures can be confirmed at the beginning of each treatment day. Also an alarm state should activate when the bottles fall below a minumum pressure.

4. Patient summary - presently at the end of each patient treatment the dose delivered that day is output on the line printer. It would be nice if a dose history for the previouse treatment days was also printed out at the end of each treatment.

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E. Beam Development in Cycle 10

A series of measurements will be required this cycle in order to complete the new beam developments. The goal is to have final dosimetry for four new treatment beams which will have 10, 15, 21, and 27 gm/cm^2 penetration after the range shifter. These beams must be capable of being collimated to 10 x 8 or smaller. Dosimetry measurements will be made on a 2, 5 and 8 cm range shifted beam. Below are the experiments required to accomplish this goal:

1. Beam tuning - Mike Paciotti has agreed to make data tapes on the 10 gm/cm^2 penetrating beam and to develop and make data tapes on the 21 gm/cm^2 penetrating beam. In addition, Mike plans to look at ways of increasing dose rates for the 10 gm/cm^2 and 27 gm/cm^2 tunes.

2. Microdosimetry - Chaim Richman will continue his work on measuring the beam quality. Information for the 2, 5 and 8 cm beams for each of the beam tunes is required so that the biological flatness of Howard Amol's range shifted beams can be verified. If time permits, some preliminary off-axis data should be taken.

3. Dosimetry - initially, these shifts will be devoted to collimation experiments. The purpose of these experiments is to determine the best collimator thickness and to look at ways of improving the design of the aperture edges. Results indicate that the shape of these edges affects the entrance dose, especially for the 27 gm/cm^2 beam. Also, very early in the cycle, the dosimetry on the 21 gm/cm^2 penetrating beam will require one shift. This new beam was determined to be necessary as it narrows the existing gap between the 15 gm/cm^2 amd 27 gm/cm^2 beams. Such a beam would not only decrease the running time of the channel at the high magnet currents, but for tumors 15-21 gm/cm^2 in depth, it should improve the beam quality and substantially increase the dose rate.

Plans are also made for 1.5 shifts of inhomogeneity and bolus studies, and approximately 1.5 shifts for development of in vivo dosimetry using silium diodes, TLD, and activation.

Finally, four shifts will be required for final dosimetry of the new treatment beams. This then divides dosimetry into one four shift experiment, one three shift experiment, and another four shift experiment, for a total of eleven shifts.

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NEW BEAM TUNE SETTINGS

TUNE 13

MAGNET	ON/OFF	CURRENT	POL	DIALS	DVM
QM01	ON	[illegible]	N	[illegible]	[illegible]
QM02	ON	[illegible]	R	[illegible]	[illegible]
QM03	ON	[illegible]	N	[illegible]	[illegible]
QM04	ON	[illegible]	N	[illegible]	[illegible]
QM05	ON	[illegible]	R	[illegible]	[illegible]
QM06	ON	[illegible]	N	[illegible]	[illegible]
QM07	ON	[illegible]	R	[illegible]	[illegible]
QM08	ON	[illegible]	N	[illegible]	[illegible]
BM01	ON	[illegible]	R	70%	[illegible]
BM02	ON	[illegible]	R	48%	[illegible]
BM03	ON	[illegible]	R	[illegible]	[illegible]

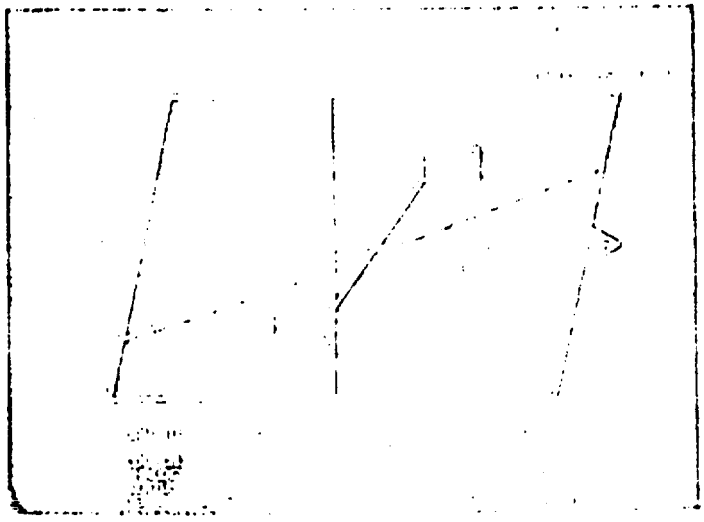
TUNE 17

MAGNET	ON/OFF	CURRENT	POL	DIALS	DVM
QM01	ON	[illegible]	N	[illegible]	[illegible]
QM02	ON	[illegible]	R	[illegible]	[illegible]
QM03	ON	0.0	N	[illegible]	[illegible]
QM04	ON	322.1	N	41%	[illegible]
QM05	ON	365.6	R	45%	[illegible]
QM06	ON	499.5	N	[illegible]	[illegible]
QM07	ON	307.6	R	[illegible]	[illegible]
QM08	ON	190.9	N	22%	[illegible]
BM01	ON	698.4	R	87%	[illegible]
BM02	ON	647.1	R	64%	[illegible]
BM03	ON	736.5	R	92%	[illegible]

TUNE 18

MAGNET	ON/OFF	CURRENT	POL	DIALS	DVM
QM01	ON	275.2	N	34%	[illegible]
QM02	ON	213.2	R	26%	[illegible]
QM03	ON	0.0	N	0%	[illegible]
QM04	ON	[illegible]	N	[illegible]	[illegible]
QM05	ON	[illegible]	R	[illegible]	[illegible]
QM06	ON	[illegible]	N	[illegible]	[illegible]
QM07	ON	[illegible]	R	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]			
QM08	ON	[illegible]	N	[illegible]	[illegible]
BM01	ON	[illegible]	R	[illegible]	[illegible]
BM02	ON	[illegible]	R	[illegible]	[illegible]
BM03	ON	[illegible]	R	[illegible]	[illegible]

GOOD WEDGE
SLIT #2 SETTINGS



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NEW BEAM CHARACTERISTICS

	LOW	MEDIUM	HIGH
Momentum	150 MeV/c	170 MeV/c	207 MeV/c
Penetration (RS at minimum)	10 gm/cm^2	15 gm/cm^2	27 gm/cm^2
Collimator used for measurements below	10 x 8	9 x 7	10 x 8
2 cm Dose Rate	4.6* rads/min.	5.9 rads/min.	2.8* rads/m
8 cm Dose Rate	2.0* rads/min.	3.8 rads/min.	1.7* rads/m
2 cm x Profile FWHM at 80%	7.2	6.4	7.8
" " " " " 50%	9.7	9.2	10.0
" " " Penumbra 80% - 20%	2.1	2.5	2.1
2 cm Y Profile FWHM at 80%	6.2	4.9	5.2
" " " " 50%	8.0	6.8	8.2
" " " Penumbra 80% - 20%	1.6	2.1	3.2
8 cm X Profile FWHM at 80%	8.4	6.4	5.6
" " " " 50%	10.0	9.0	8.7
" " " Penumbra 80% - 20%	1.7	2.7	2.5
8 cm Y Profile FWHM at 80%	6.8	5.0	5.4
" " " " 50%	8.0	7.0	7.8
" " " Penumbra 80% - 20%	1.4	2.2	2.5

* These rates are projected based on a proper operation of channel. At the time these measurements were made, channel was 30% below maximum delivery.

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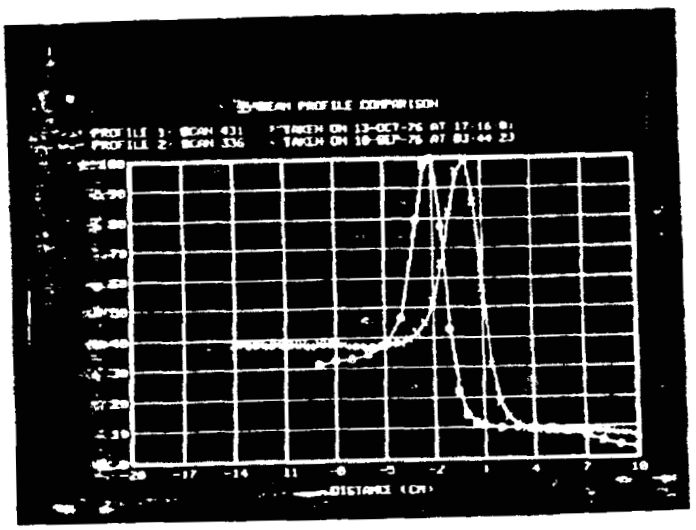
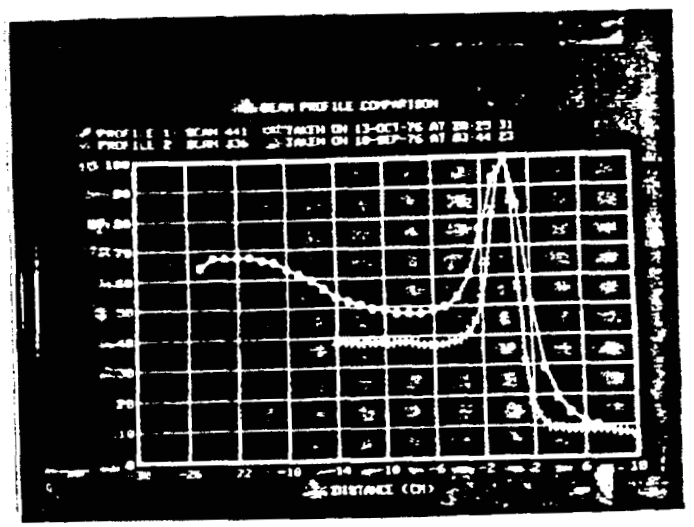
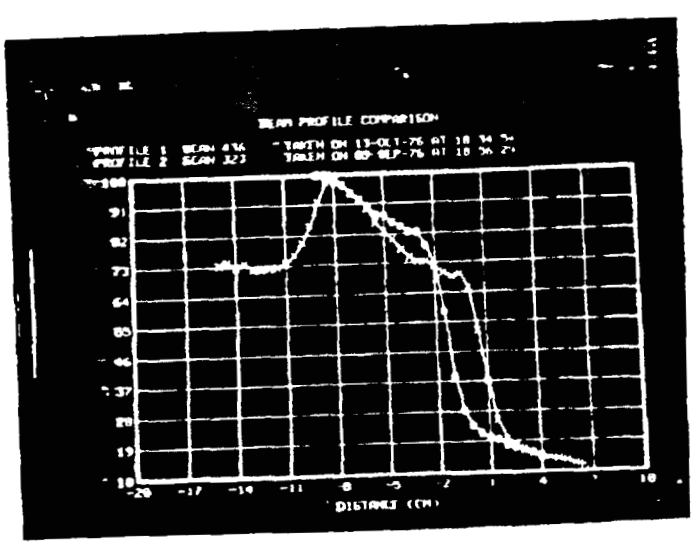
Central Axis Depth Dose For New Beam Tunes



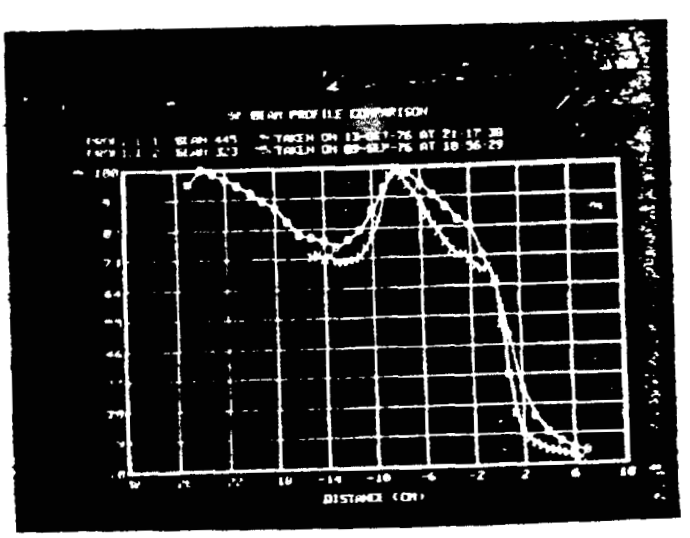
O— Low Momentum 2cm Peak
X— Medium Momentum 2cm Peak



O— High Momentum 2cm peak
X- Medium Momentum 2cm Peak



O— Low Momentum 8cm peak
X- Medium Momentum 8cm peak



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O- High Momentum 8cm Peak
X- Medium Momentum 8cm

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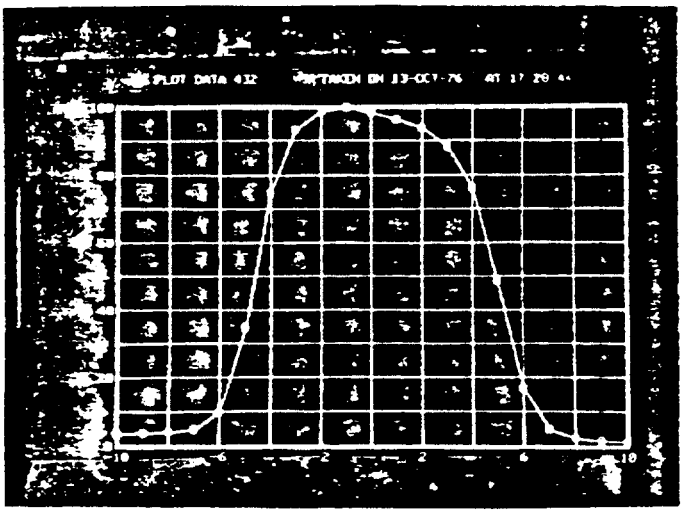
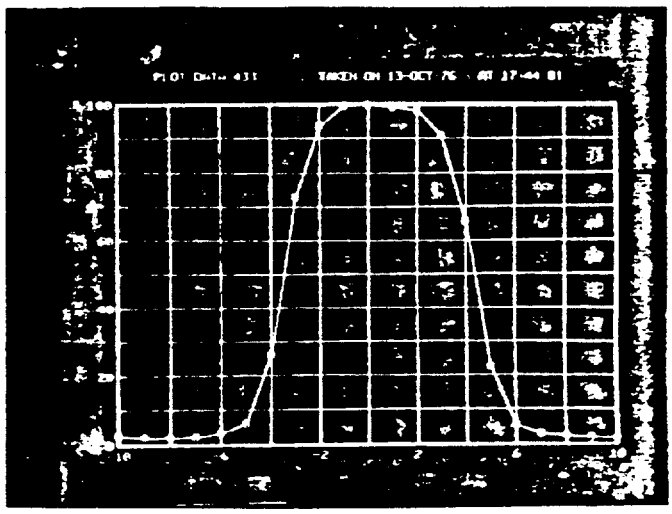
Beam Profiles for Low Momentum Beam

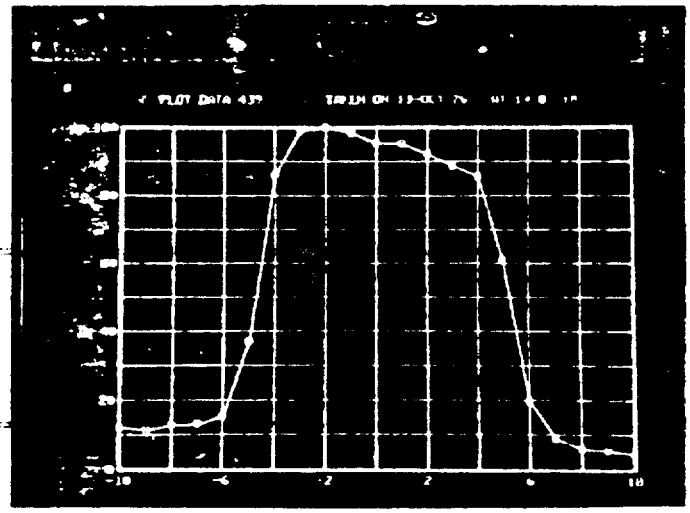
10X8 Collimator



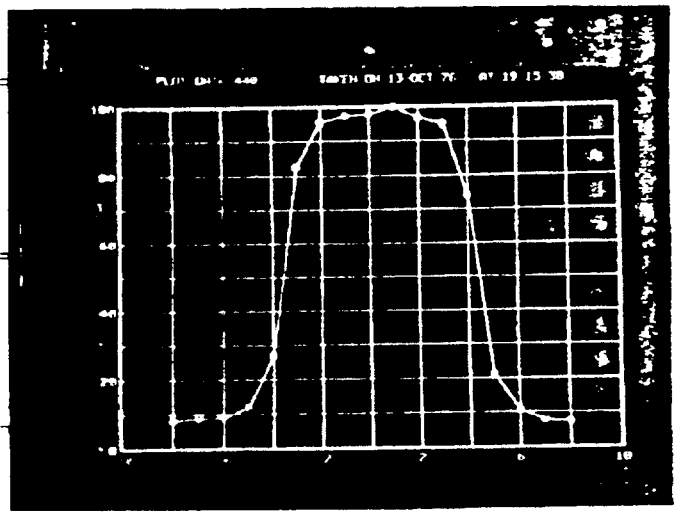
X Profile 2cm Peak



Y Profile 2cm Peak



X Profile 8cm Peak



Y Profile 8 Cm Peak

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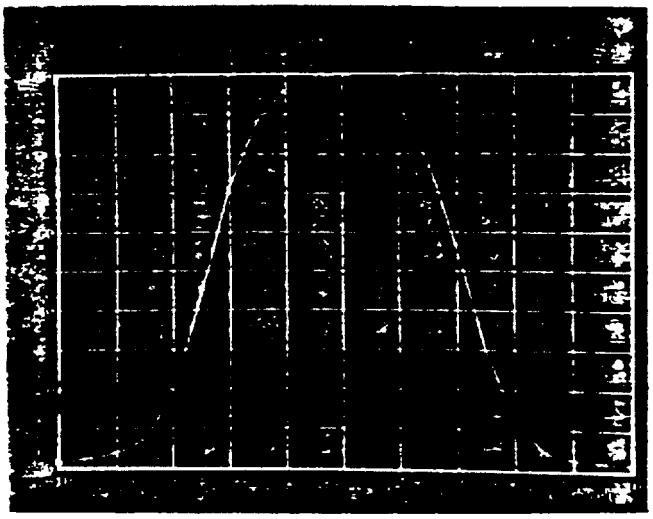
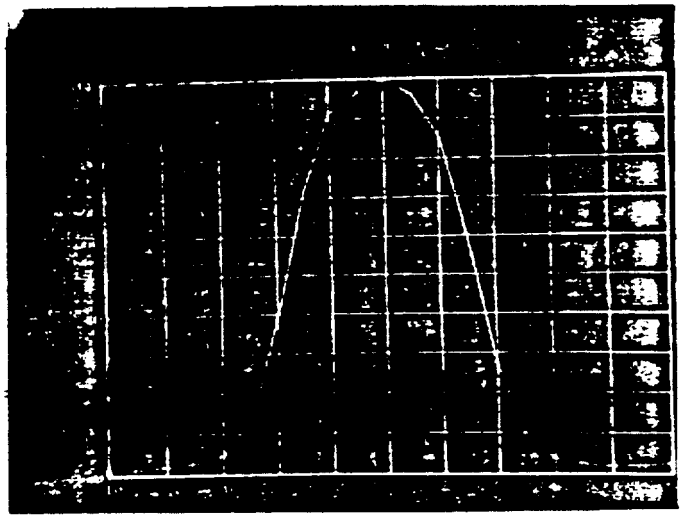
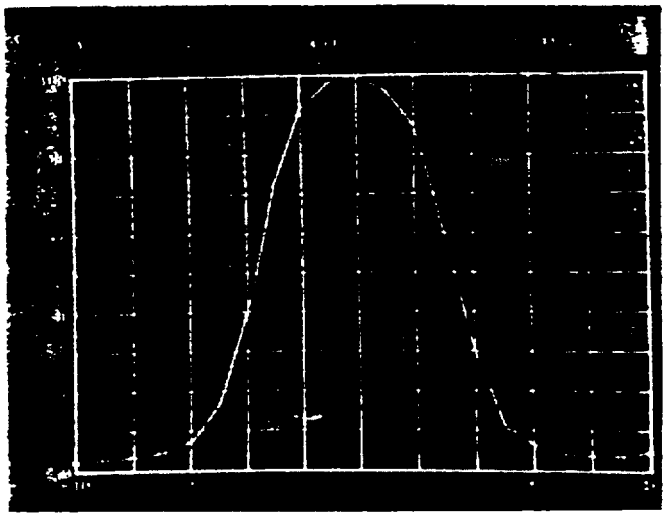
Beam Profiles for Median Momentum Beam
9X7 Collimator



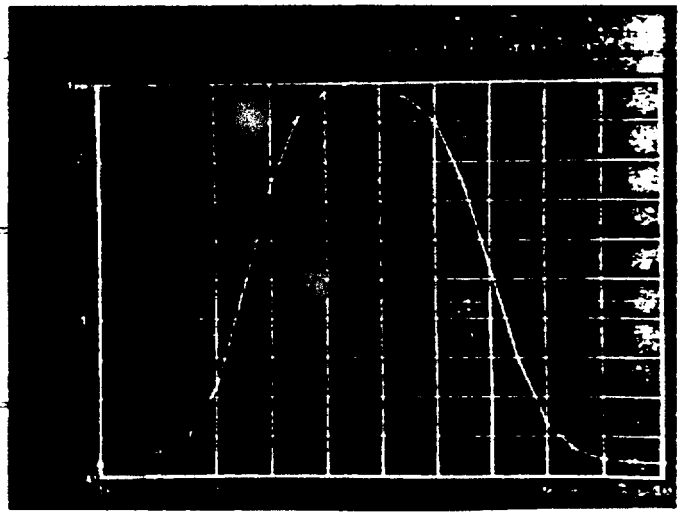
X Profile 2 cm Peak



Y Profile 2 cm Peak



X Profile 8 cm peak



Y Profile 8 cm Peak

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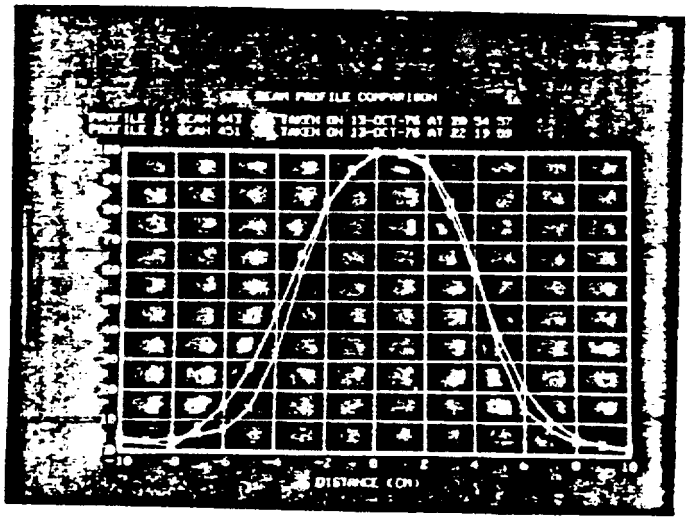
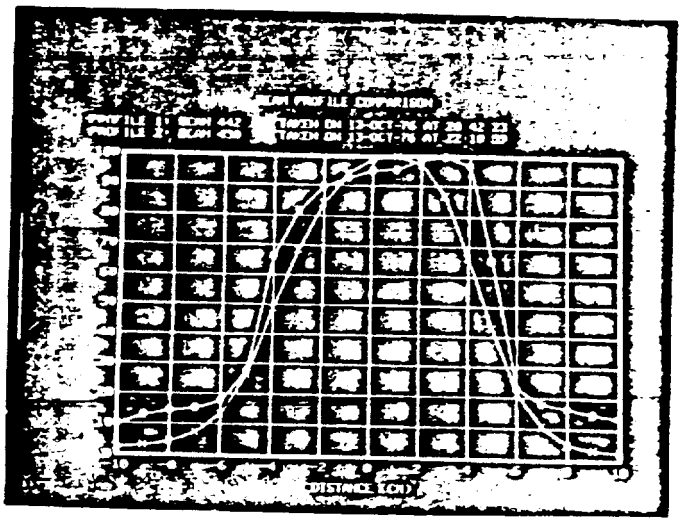
Beam Profiles for High Momentum Beam

10x8 Collimator





Y Profiles
0 – 2cm Peak
X – 8cm Peak

X Profiles
0 – 2cm Peak
X – 8cm Peak

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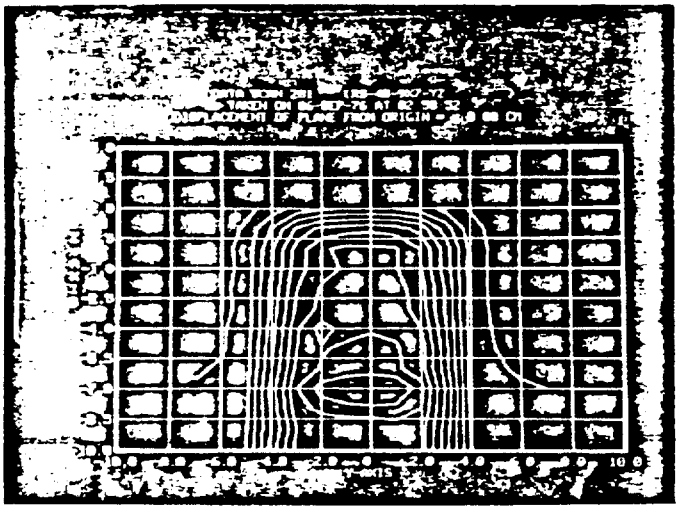
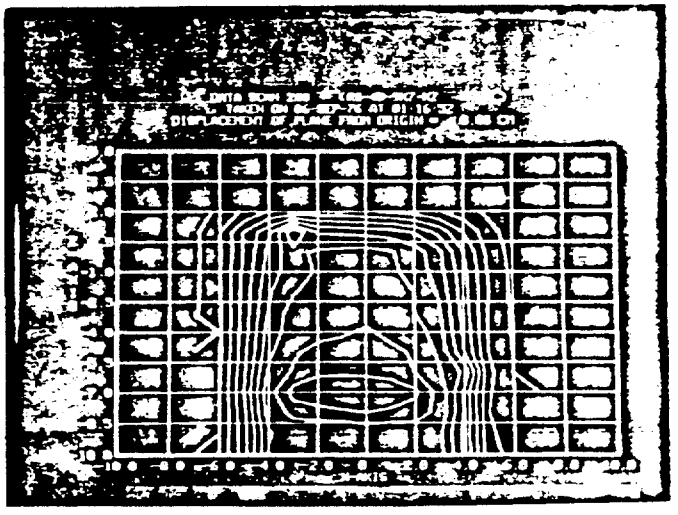
Isodose Contours For Medium Energy Beam

9X7 Collimator

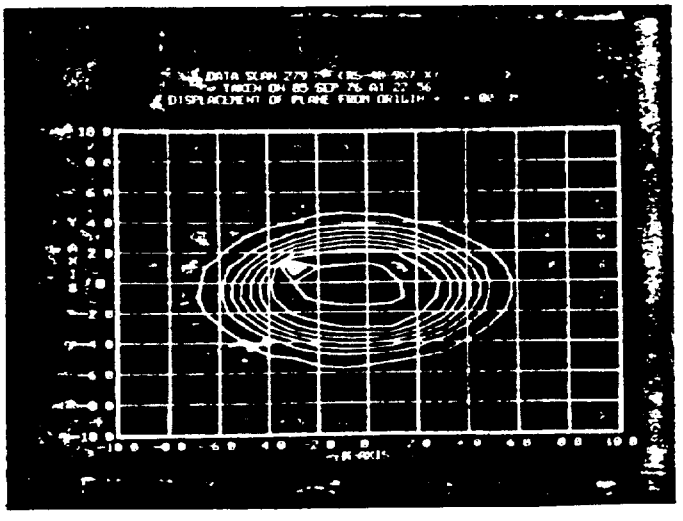
Dose Flattened 8 cm Peak



YZ Plane



XZ Plane



XY Plane

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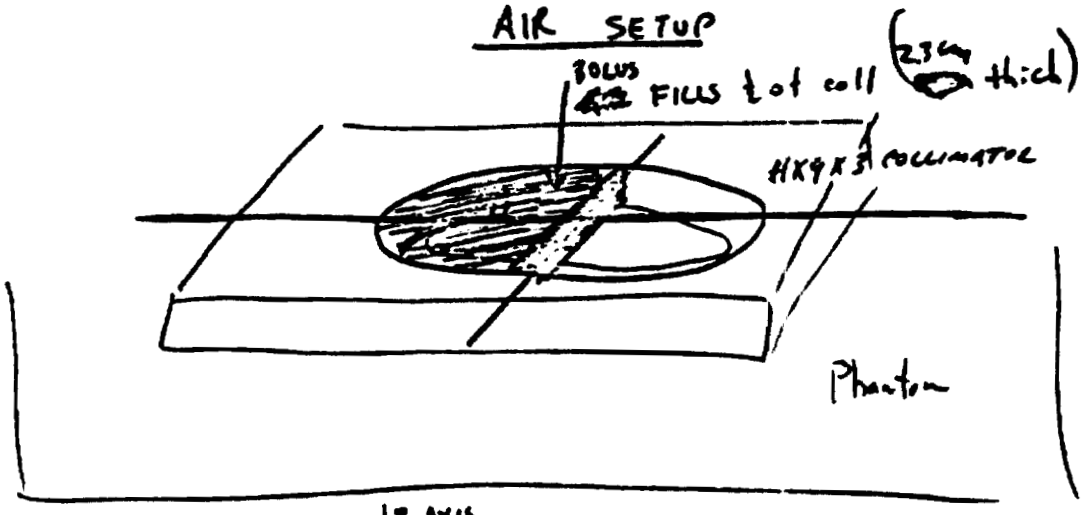
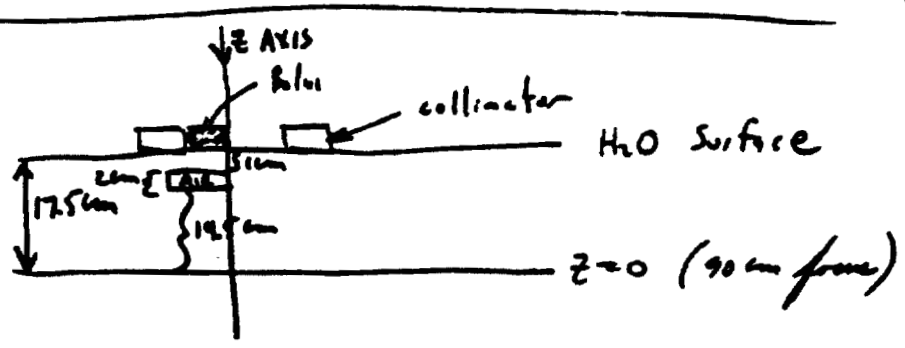
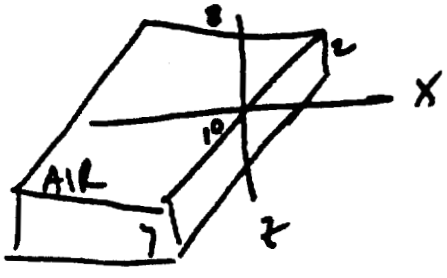
Results of Inhomogeneity Exp.

Tune 13 : MAGNETS = Mike's Run 428
Good Wedge

11 x 9 Collimator







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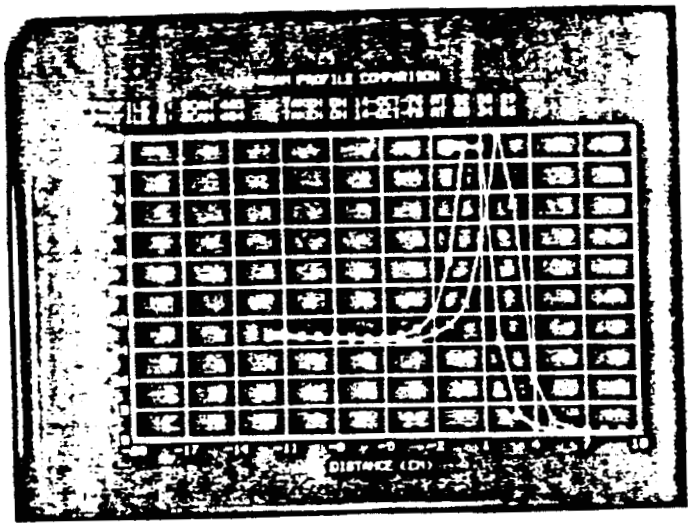
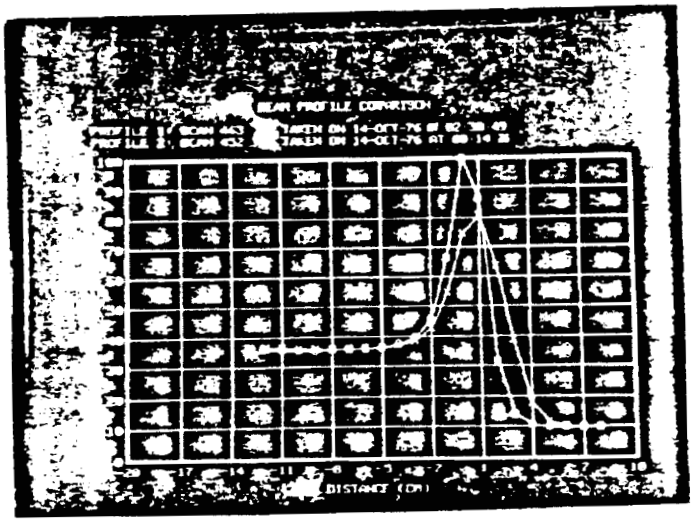


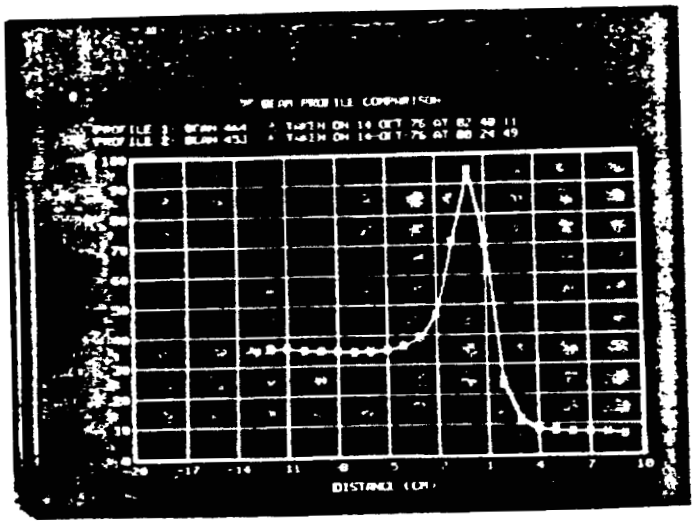
Z Scan, Y=0, X=-3
Under Inhomogeneity

o — Open Field
x — Air Inhomogeneity



Z Scan, Y=0, X=0
Under Inhomogeneity Edge

o - Open
x - Air Inhomogeneity



Z Scan, Y=0 X = +3
Away From Inhomogeneity

o - Open
x - Air Inhomogeneity

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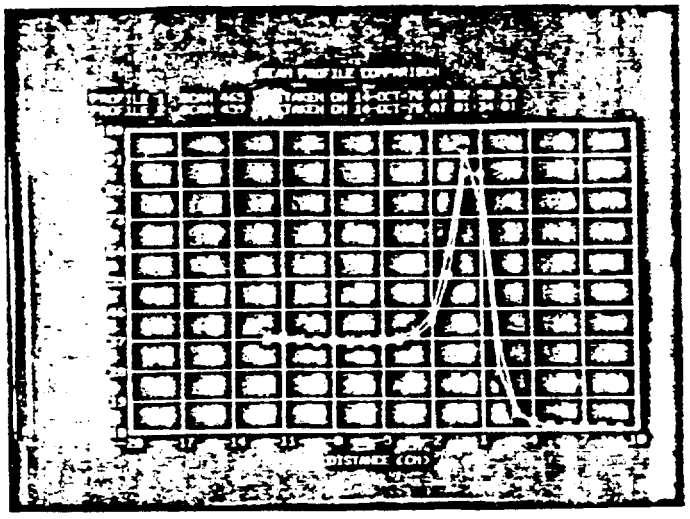
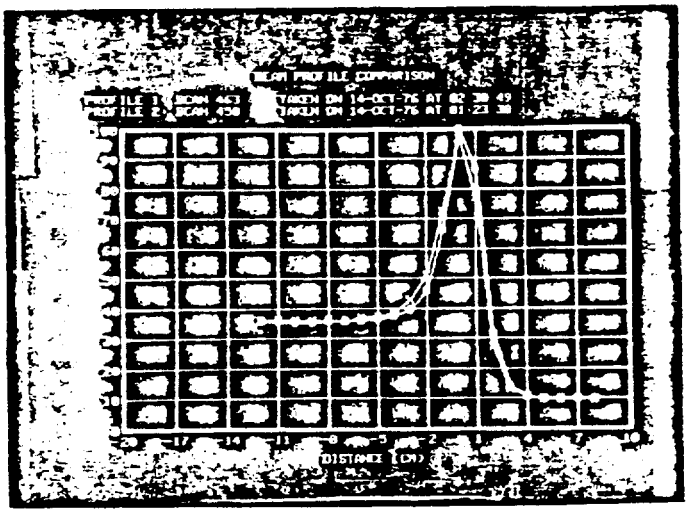


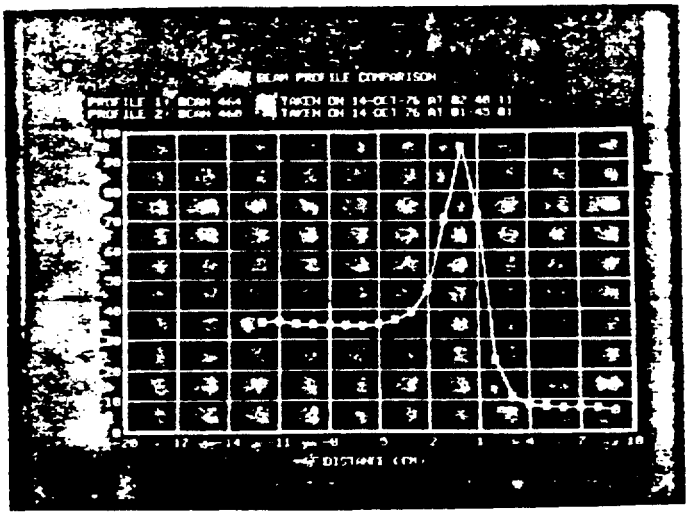
Z Scan, Y=0, X= -3
Under Inhomogeneity

o- Open
x- Air Inhomogeneity + Bolus



Z Scan, Y=0, X=0
Under Edge of Inhomogeneity

o- Open
x- Air Inhomogeneity + Bolus



Z Scan, Y=0, X=3
Away From Inhomogeneity

o- Open
x- Air Inhomogeneity + Bolus

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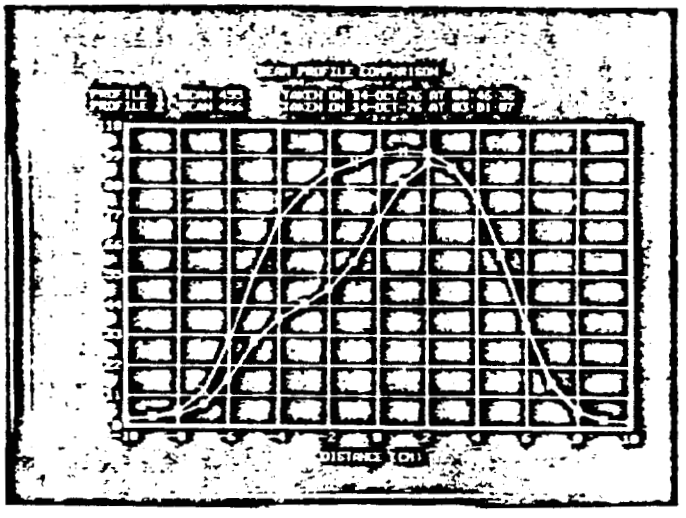
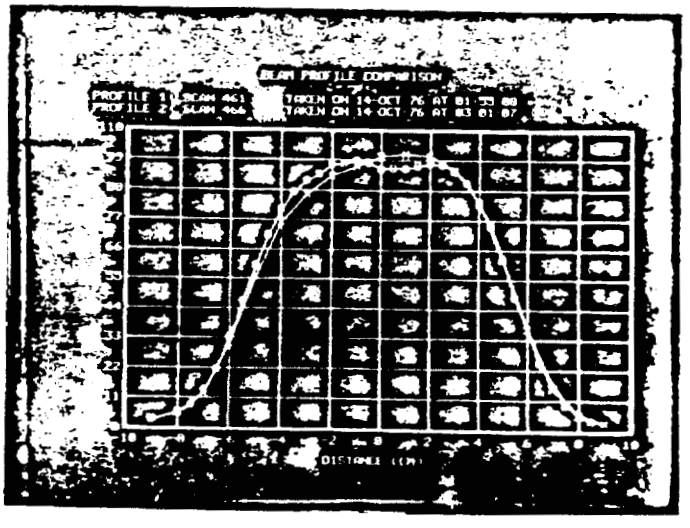


X Scan, Y=0, Z=0 (Peak,

o Air Inhomogeneity
x Open



X Scan, Y=0, Z=0

o Air Inhomogeneity + Bolus
x Open

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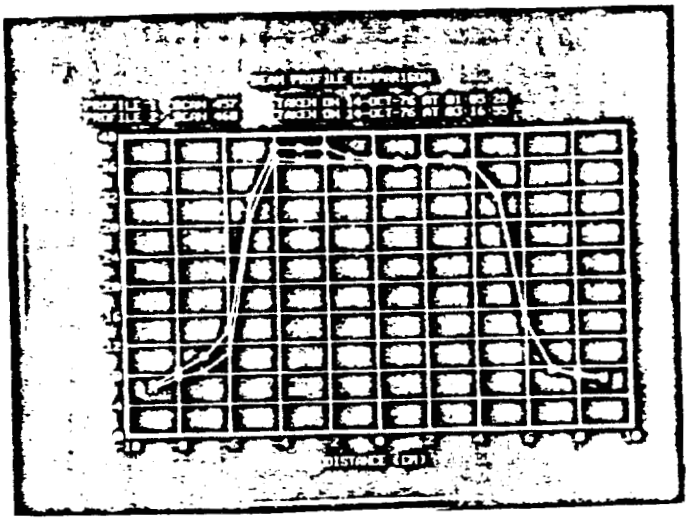
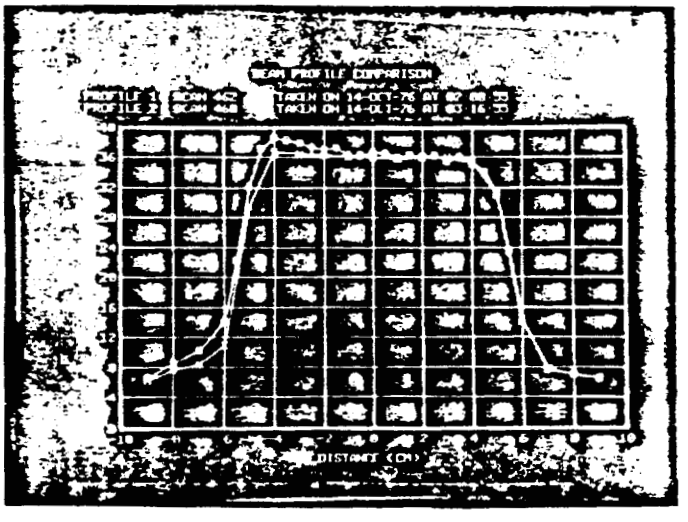


X Scan, Y=0, Z = -11.5

o Air Inhomogeneity
x Open



X Scan, Y=0, Z = -11.5

o Air Inhomogeneity + Bolus
x Open

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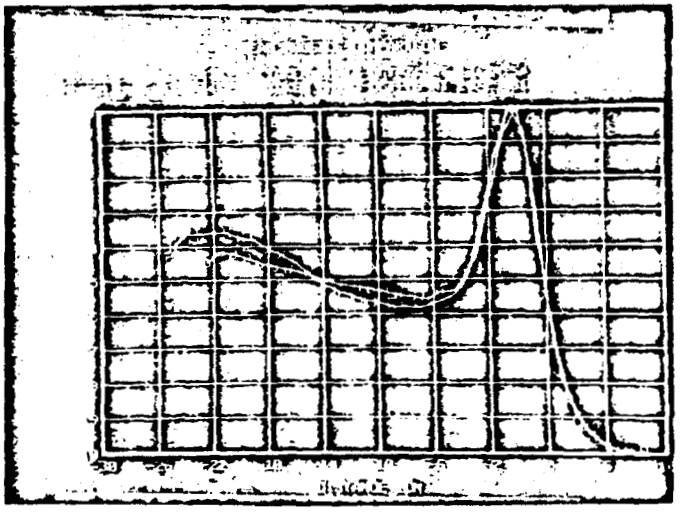
Collimator Effects on High Momentum Beam

10X8 Collimator

2 Cm Peak



O 10X8X3 below 11X9X3

X 10X8X6

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