

NSRL Manual

This manual is intended for both the first-time user and the “old hand”. You will find many useful pointers and explanations here, but the depth is not so great as to render the manual too long-winded and unreadable. At various points, the interested reader is referred to web-sites containing more information about the subject of interest.

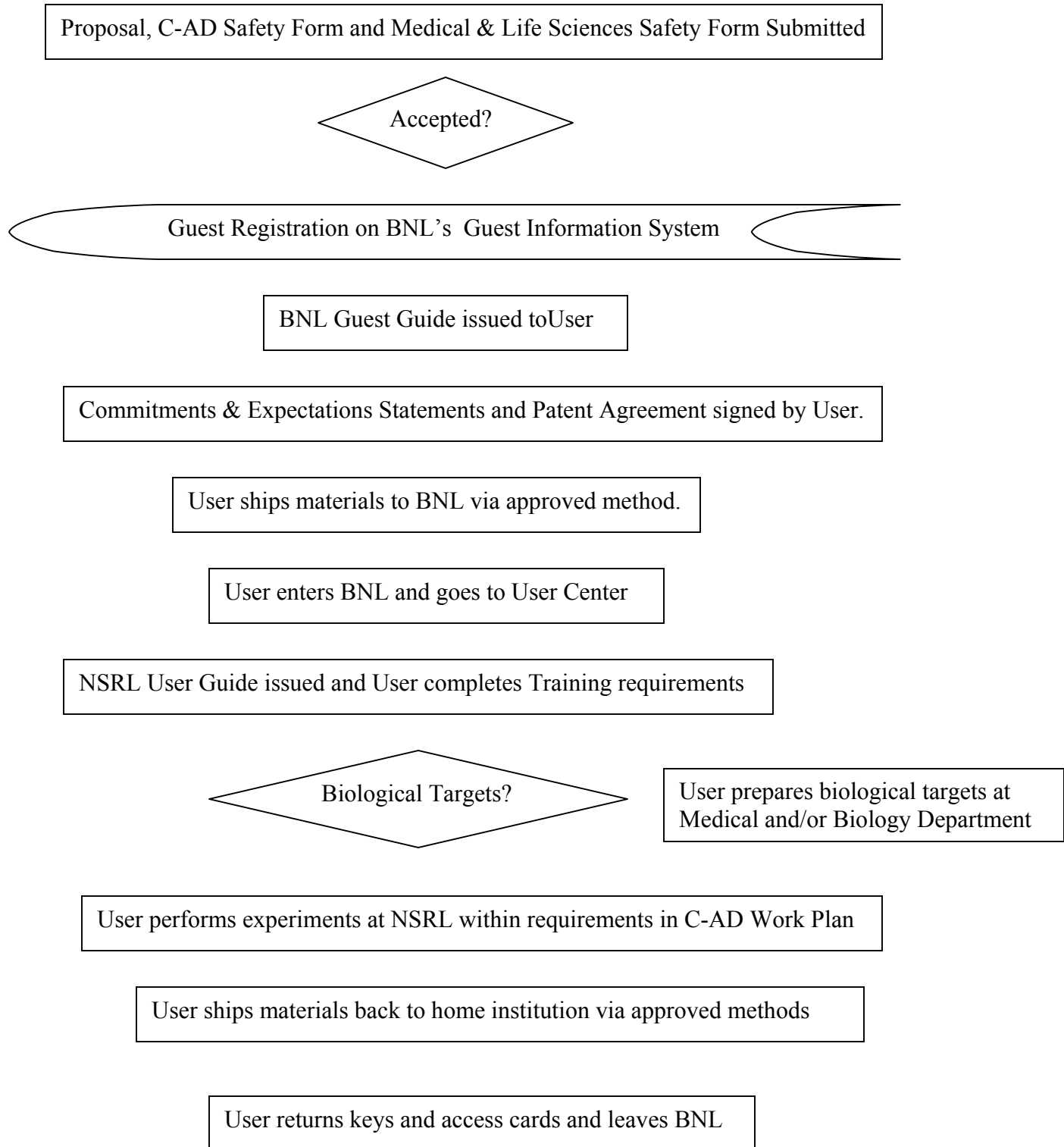


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User Flow Chart



Orientation

General visitor information for on site and off site amenities (including restaurants, shopping, beaches, culture etc) can be found on the web at <http://www.bnl.gov/bnlweb/visitorsguide.html>. *In addition this site provides the most up to date information regarding identification requirements for site access – click on “Important ID requirements for visitors”.*

Before Arriving at BNL

IF YOU HOLD A VALID BNL ID CARD, STEP #1 IS NOT REQUIRED

Step 1: Registration

NEW USERS. Users who do not hold a BNL ID card MUST pre-register on the web. Do this BEFORE arrival to BNL. On the web go to the BNL Home Page (www.bnl.gov) and click on the “Guest Registration” link (<https://fsd84.bis.bnl.gov/guest/>). The required forms can be filled out and submitted on line. It is important that this is done as soon as possible since there is an approval process that takes some time.

EXPIRED BNL ID. Contact the Users’ Center at (631) 344-5975 or userscenter@bnl.gov

Step 2: Arrival Notification

Guests must notify Brookhaven of their actual arrival and anticipated departure dates. They can do this at <https://fsd84.bis.bnl.gov/guest/guestlog.asp>. A guest number is required to access this system. New guests will receive BNL ID numbers via e-mail (Step 1).

Step 3: Reserve Housing

Contact the BNL Housing Office at 631-344-2551 or reserve on line at <https://fsd84.bis.bnl.gov/staffservices/HousingResForm.asp>. Be advised the summer period is usually very busy so reserve early.

Step 4: Training

WHAT TRAINING IS REQUIRED: Training requirements for each of the NASA experiments can be found on the NASA Radiobiology Training Page. For links and directions on how to take these courses go to

<http://www.bnl.gov/userscenter/Training/training.htm> and click on the “NSRL” link. .

TRAINING STATUS: For those who have been here before, you can check your training status on line at <http://www.bnl.gov/userscenter/Training/training.htm> and click on “My Training History”. You must have a current guest number to do this. You will see what you completed and how long the qualification is valid. If you don’t have a guest number, you will receive one via e-mail after your registration form has been submitted and approved (see Step #1). If you forgot your number or have a question about it contact the Users' Center - (631) 344-5957 or userscenter@bnl.gov.

TAKE ON-LINE COURSES BEFORE YOU ARRIVE: This will shorten your check-in time substantially. It is recommended that you print out any confirmation pages made available to you at the completion of a course or note the date that you took a course if confirmation pages are not available. Bring this information with you.

Step 5: Forms To Submit

(Radiation Worker Exemption, Ground Support Requirements Document, IRB and IACUC)

RADIATION EXEMPTION

Employees from DOE Facilities: If you have a valid Radiation Worker I certificate from a DOE facility, complete exemption form available on line at <http://www.bnl.gov/userscenter/DOEExemption-Waiver%20Form.pdf> , sign form, make a copy of your training certificate or training card from your home institution and mail it to the RHIC & AGS Users’ Center, Brookhaven National Laboratory, Building 355A, Upton, NY 11973. No challenge exam is necessary.

Employees from Non-DOE Facilities: To qualify for the challenge exam equivalent of the course (rather than having to complete the 8hr classroom course) complete the exemption form available on line at <http://www.bnl.gov/userscenter/Non-DOEExemption-Waiver Form.pdf>, sign form, and mail to the RHIC & AGS Users’ Center, Brookhaven National Laboratory, Building 355A, Upton, NY 11973. A challenge exam is required upon arrival. A Study Guide can be found at http://training.bnl.gov/Study_Guides/New_Folder/RWT002.PDF.

GROUND SUPPORT REQUIREMENTS DOCUMENT (GSRD)

Read the [GSRD documentation](#) and complete the [GSRD Form](#) and the [User Questionnaire](#). E-mail this directly to Marcelo Vazquez at vazquez@bnl.gov.

INSTITUTIONAL REVIEW BOARD and/or INSTITUTIONAL ANIMAL USE and CARE COMMITTEE APPROVALS:

If you are using animals and/or human cells or blood you must have approval through the Office of Research Administration (ORA). Please contact Darcy Mallon at (631) 344-3362 or mallon@bnl.gov. Human cell culture work that is exempt must still be reviewed by the ORA.

Step 6: Open a BNL Financial Account

You must have a valid BNL account number before coming to conduct experiments. For instructions on how to open an account go to http://www.bnl.gov/userscenter/financial_accounts.htm. Email the account number to Marcelo Vazquez (vazquez@bnl.gov) at least 30 days prior to the run.

You must order controlled substances from the BNL Pharmacy. You may **NOT**, under any circumstances, bring controlled substances to BNL. You can use your BNL financial account to make purchases. Contact Marcelo Vazquez for assistance vazquez@bnl.gov

Step 7: Mycoplasma Testing Certification and Transportation Considerations

Mycoplasma Testing for Cell Cultures Anyone who is bringing a cell culture to BNL (either into the NSRL Tissue Culture Facility or the Medical Tissue Culture Facility) must have it certified "mycoplasma-free" no more than one month prior to the beginning of the run. The certification should not be done in house unless you have a certified testing lab. Here are a couple of companies that will do the testing for you. Bionique Test Labs, Saranac Lake NY 518 891 2356, Web site <http://www.bionique.com/> (Their M-100 runs 4 shippers for \$140. The CELLshipper® is a DNA fluorochrome assay for cell culture contamination. Purchase the slides and store in your lab for use at your convenience. Simply add the cell sample, fix and dry. Send the slide (hazard-free) to Bionique for diagnosis). They generally return the results to you promptly. Another company that will do the testing is ATCC. ATCC is in the mycoplasma testing business. Their site for their service is <http://www.atcc.org/ProgramsAndServices/LabSvcs.cfm>.

Completed certificates should be faxed to Ann Emrick at (631)344-6398. Any questions contact Betsy Sutherland (bms@bnl.gov) or Ann Emrick (emrick@bnl.gov)

Transportation of samples to/from BNL and on BNL site: For transportation of biological products, consult the shipper. If you are transporting samples by car consult

your shipping department or contact Bob Colichio ((631) 344-8440 or colichio@bnl.gov) for assistance.

Step 8: Arrival at BNL

BRING IDENTIFICATION WITH YOU

Identification requirements depend on your classification. Foreign nationals, permanent resident aliens and Canadian citizens are all treated differently with regards to required identification. Refer to the BNL Home Page (www.bnl.gov) and click on the “Visitors Guide” link (<http://www.bnl.gov/bnlweb/visitorsguide.html>) and then on the “Important ID requirements for visitors” link. This site provides the most up to date information regarding identification requirements for site access.

Instructions on identification requirements for subsequent visits to BNL will be provided upon check-in. Identification documentation is required for guest registration, the issuance of appointments and any subsequent appointment renewals. A Brookhaven photo ID card cannot be issued without the appropriate identification.

Visa advisory: Foreign nationals intending to visit BNL under the visa waiver program or in a business classification should be sure that the INS Officer at the port of entry marks their arrival/departure record (form I-94) with either W/B or B-1 visa for business status.

Foreign nationals with the following visa classifications are NOT eligible to hold a BNL appointment: W/T, B2, J-2, and H-4. (Accompanying family members may hold W/T, B2, J2, or H4 visas.)

Step 9: Pick Up Your Room Key

Keys can be picked-up at the Housing Office, Building 179, Monday through Friday between the hours of 8:00 am and midnight. During other times, keys can be picked-up at Police Headquarters, Building 50.

Step 10: Check-In Procedure

Check in at the RHIC & AGS Users’ Center, Bldg. 355A on Brookhaven Avenue. Business hours are 8:30 a.m. to 5:00 p.m., Monday through Friday. Ask for directions to the Users’ Center at the front gate.

Obtaining a Computer and Email Account

In order to apply for a computer account at BNL you must have a valid employee or guest number registered with [Human Resources](#) and have completed the BNL On-Line Cyber Security training. Follow the instructions available on the web at <http://accountrequest.bnl.gov/>

QUESTIONS: Contact list follows:

BNL Contacts

Primary Contact (Medical):

Marcelo Vazquez

Phone: (631)344-3443

Cellular Phone: (631)786-0516

Fax: (631)344-5311

vazquez@bnl.gov

Physics Liaison Scientist (C-AD)

Adam Rusek

Phone: (631) 344-5830

rusek@bnl.gov

Logistical and Technical Assistance (Biology and Medical Departments):

Peter Guida

Phone: (631)344-2913

Fax: (631)344-5311

guida@bnl.gov

Logistical and Technical Assistance (Medical Department):

Stacey Koslosky

Phone: (631)344-7842

Fax: (631)344-5311

srussell@bnl.gov

Training and Experimental Review (Biology)

Ann Emrick

Phone: (631)344-5756

emrick@bnl.gov

Brookhaven Laboratory Animal Facility (Medical Department):

MaryAnn Kershaw

Phone: (631)344-3620

kershaw@bnl.gov

Controlled Environment Radiation Facility (Biology Department)

Richard Sautkulis

Phone: (631)344-3386

sautkulis@bnl.gov

NSRL User Support Building (C-AD):

Dave Phillips

Phone: (631)344-4671

phillips@bnl.gov

**Collaborator Appointments:
RHIC and AGS Users' Center**
Phone: (631)344-5975
[http://www.bnl.gov/userscenter/
userscenter@bnl.gov](http://www.bnl.gov/userscenter/userscenter@bnl.gov)

BNL Housing Office
Phone: (631)344-2551
Online Form: <https://fsd84.bis.bnl.gov/staffservices/housing.asp>
Note: When making reservation reference NASA Radiobiology Program

**Scientific Advisory Committee:
Betsy Sutherland**
Phone: (631)344-3380
<mailto:bms@bnl.gov>

Summary of Required Training

Item	Preparation/Prerequisite	Time requirement	Comment
All training	Guest registration	Done online from home institution	Need ~ 30 days processing for clearance. Guest appointments from sensitive countries require ~ 90 days
Radiation Worker I, Part 2	<ul style="list-style-type: none"> Complete RWI Part 1 on line Review study guide 	4 hr course and exam	Qualification is valid for 2 years after passing exam
NSRL Radiobiology	<ul style="list-style-type: none"> Pass RWI, Parts 1 and 2 Review study guide 	2 hr course & exam Tour of facility	Qualification is valid for 2 years after passing exam
Iris Scan	<ul style="list-style-type: none"> Pass NSRL Radiobiology and RWI 	30 min, go to Main Control Room	Practice access at NSRL
Benchtop Dispersibles	RWI, Parts 1 and 2	3 hr course	To handle activated samples or radioisotope tracers Qualification is valid for 2 years after course
Experiment-specific training	<ul style="list-style-type: none"> Submit beam time proposal Beam time approved Life Sciences Experimental Safety review identifies training requirements 	Varies, depending on experimental protocol	Much can be done on line at home institution Animal training requires course at BNL. Qualifications vary, typically 2 years.
BNL ID card (NSRL encoded) TLD	<ul style="list-style-type: none"> Guest Registration approved RWI NSRL Radiobiology 		Take form showing completion of training requirements to AGS/RHIC Users' Center; ID card and TLD issued upon validation of training.

NASA Space Radiation Laboratory

The NASA Space Radiation Laboratory (NSRL) was constructed at Brookhaven National Laboratory, in collaboration with NASA. This new facility takes advantage of heavy-ion and proton beams from the Brookhaven Alternating Gradient Synchrotron (AGS) Booster accelerator for radiation effect studies for the space program.

Radiation fields encountered in space may cause deleterious effects in humans. These effects are of special concern for prolonged space missions beyond the protective terrestrial magnetosphere. Before such missions can be undertaken, a more detailed understanding of these effects is required to allow planning and implementation of protective countermeasure. This facility was constructed to address these issues.

Heavy ions from the Brookhaven MP-6 tandem accelerator or protons from the Brookhaven LINAC are transported to the Booster synchrotron for acceleration and extraction to the NSRL. Concurrent operation of the Booster for space radiation research and other kinds of research applications is achieved by utilizing independent tandem injectors. The beam species and energy for both applications is independent. Beams from either Tandem will be switched into the common injection line. At the Booster a new slow extraction system has been implemented which required extensive accelerator modifications and rearrangements. A new beam line and tunnel enclosure was built to transport the extracted beam to the experimental facility. Uniform beam intensities will be provided over rectangular areas ranging in size from about 1 cm to over 20 cm.

Existing on-site facilities, such as the Long-Term Support Facility (LTSF) located at the Medical Department has extensive tissue culture, molecular biology and animal handling installations are also available (see below). Dosimetry and local access control is provided through a local facility control room.

A user support building was constructed to provide experimental space and support facilities. A labyrinth connects the experimental area with the User Support Building. The target room is provided with a concrete beam stop imbedded in the back wall. The entire facility is shielded by 15 feet of earth equivalent shielding over the top of the target rooms and transport lines. The laboratory building contains support laboratories, including temporary biological specimen holding and preparation areas, as well as radiological laboratories for work with cell cultures and tissues. Also included are a dosimetry control room, a mechanical service equipment area and rooms for radioactive storage and miscellaneous items.

The User Support Building (Bldg. 958) layout is shown below (Fig. 1).

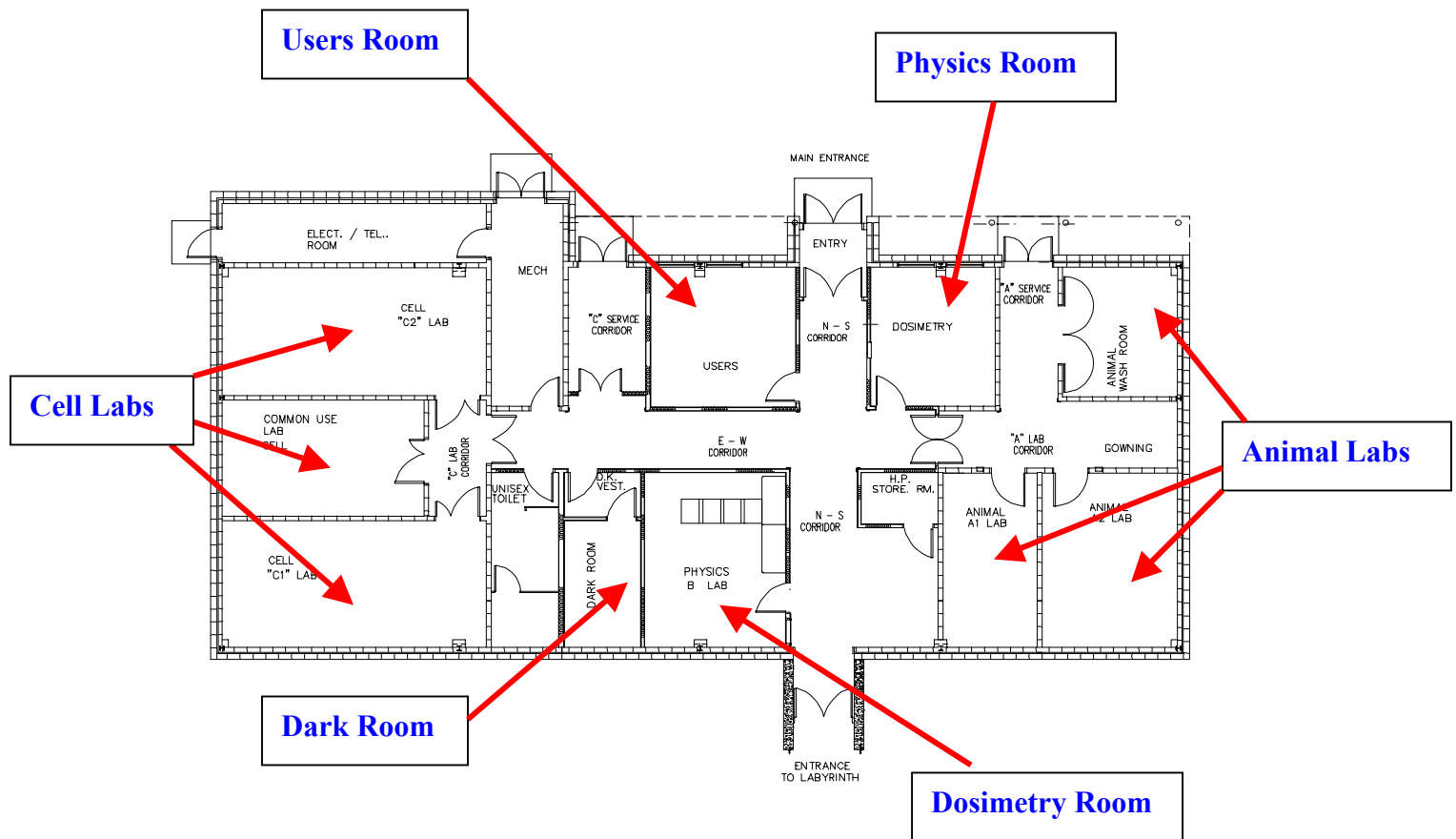


Fig. 1. NSRL User Support Building

Users Break Room

The Users' Break room is provided with a conference table and chairs, plus stacking chairs for additional seating. A white board and erasable markers are provided. Hot and cold tap water are available, as well as Instant Hot Water faucet for beverage preparation. A User Computer (PC) with Microsoft Windows 2000, Office 2000 and NSRL Dosimetry programs as well as web access is available. A multi-purpose FAX/scanner/printer is connected to the computer. A small refrigerator and microwave are provided.

Information for on-site (and off-site) food resources can be found on the web at <http://www.bnl.gov/bnlweb/visitorsguide.html>.

Animal Laboratories

The animal laboratories contain two rooms dedicated to animal short-term storage (24hrs), handling and pre-irradiation procedures, and one washing room dedicated to clean cage racks and mobile carts. The animal rooms are temperature controlled, have hot and cold tap water. The walls and floor are fully washable and impervious to moisture. The animal laboratories have independent 100% fresh air ventilation system. Each laboratory can handle 400 mice or 200 rats per room (depending of number of animals per cage). A limited number of carts and tables are available. In addition, both rooms have air connections for gaseous anesthesia systems (e.g. Isufluorane). Both rooms have computers for dosimetry and communication with the main control room and dosimetry physicists.

Cell Laboratories

The cell culture facilities contain two rooms dedicated to cell handling and one central common use room. The cell handling rooms are equipped with standard laboratory benches and a sink with emergency eye wash. They contain Baker Biological Safety Cabinets with gas and vacuum (cell culture hood), Forma CO₂ incubators and Bellco dry Roll-in Incubators, as well as Nikon inverted microscopes, water baths and clinical and microcentrifuges. One incubator is available for use with approved dispersible radioisotopes. These rooms have hot and cold tap water and house-distilled water. A limited number of carts and tables is available. Both rooms have computers for dosimetry and communication with the main control room and dosimetry physicists. The central common use room contains the water purification system, refrigerator-freezer, (water) ice machine that provides flaked ice, and a recirculating chemical hood for small quantities of volatile materials approved by the Collider-Accelerator ES&H for use at NSRL. It also contains a cabinet for storage of small quantities of volatile substances. In a nearby hall both dry ice (solid CO₂) and liquid nitrogen are available.

Dosimetry Room

All the cables from the cave terminate in this room. There are four racks of electronics, three of which house the dosimetry and accelerator interface electronics. The fourth one is intended for the physics experiments electronics, as well as other future additions. The nitrogen bottles for the dosimetry ion chambers as well as the bubblers for the return lines are also placed in this room.

The dosimetry can be controlled from the physics room or the MCR.

Physics Room

The dosimetry room is equipped with some desks, chairs and a PC, from which the dosimetry system is controlled, monitored and read into records. This particular PC can record and store dosimetry data in a number of ways (CD, ZIP, floppy disk, static memory etc.), so users can leave with the record of their choice.

Dark Room

A photographic dark room is available. It has standard laboratory benches and cabinets, and hot and cold tap water. A film processor with developer and fixer are provided.

Long-Term Support Facility (Medical Department)

Laboratories: The NASA-Medical Long-Term Support Facility includes 4 fully equipped tissue culture labs, 1 immunohistochemistry lab and 1 molecular biology laboratory. (For a more detailed description of the facility: new web address TBD)

Equipment: Equipment that are readily available include: FACS-Calibur 4-channel flow cytometer (Becton Dickinson), 13 CO₂ water-jacketed incubators, 3 Coulter Model ZM counters for cell counting, 2 autoclaves, liquid scintillation counter (Beckman Instruments, Inc.), enzyme immunoassay plate reader (model MRX; Dynatech Laboratories, Inc) interfaced with a PC compatible computer for optical density readings in ELISA plate wells and for processing data, 2 table-top centrifuges, 4 microfuge, a high-speed refrigerated centrifuge, 2 conventional upright refrigerators, fume hood, six 6 ft Biogard laminar flow hoods, freezers (conventional, Revco 70°C, and 3 liquid nitrogen tanks), water baths, a pH meters, computer based image analyzer systems (ImageTools, MIT), NIKON microscopes including inverted, automatic liquid dispensers, an ultra-pure water distillation apparatus. PC computers with software for statistics, graphics, and word processing are available.

In addition, LTSF shared the following facilities: (i) Microscopy Facility which includes 3 fluorescent microscopes (upright and inverted) with CCD digital camera and image processing software, and 2 light microscopes; (ii) Histology Facility for paraffin-based histology which includes an automated vacuum tissue processor, embedding workstation, ovens, microtomes, and fume hoods; and (iii) Research Darkroom for autoradiography and x-ray film processing, and for DNA agarose electrophoresis gel photodocumentation.

Brookhaven Laboratory Animal Facility (BLAF): Animal studies at BNL are carried out under the auspices of the BNL's Institutional Animal Care and Use Committee (IACUC). The animal Care Facility in the BNL medical Department is available to carry out all aspect of Animal care with high standards of quality under the direction of a veterinarian. The research conducted at BNL has National Institutes of Health (NIH) Assurance number A310-01 and has been accredited for Animal care and use by the American Association of Animal Care, Inc. (AAALAC) since 1986. Each research protocol is reviewed and approved by the BNL IACUC. BNL is listed with the U.S. Department of Agriculture (USDA) and complies with the regulations governing Animal care and use. It is BNL's policy to comply with all other relevant local, State and Federal regulations concerning Animal care and use. The Animal facility is located in the Medical Department. Most animals housing in the facility is the conventional type with a clean/dirty corridor system. Minimal hazard containment facilities, with separate air

handling, filtration/absorption systems are available for radioisotope tracer experiments, and for housing post-chemical exposure animals. The following support areas are included in the facility: animal receiving room, quarantine, isolation, surgery preparation, necropsy, diet kitchen, food storage, bedding storage, cage washing, clean storage, lounge, showers, lockers and a procedure lab.

The Beam Line and Beams at NSRL

The NSRL beam is extracted from the Booster and transported 100 meters to the target room. The beam is extracted from the booster using a third integer resonance extraction technique similar to that used in the AGS. Two septum magnets (thin-D3 and thick-D6) are used to redirect the beam from the Booster to the transport beam line.

A variable position vertical collimator and an eight position rotating foil/flag wheel is located between the two septa magnets. The collimator is used to adjust the beam intensity. The stripping foils/wires are used to fully strip (if necessary) ions emerging from the Booster as well as multiple scatter the beam. The idea is to multiple scatter the beam enough to force a non-gaussian beam to become approximately gaussian and therefore amenable to the use of octupoles to flatten the beam. The complement of foils etc. used for the first radiobiology experiments in July 2003 is as follows (positions on the foil stripper wheel are numbered clockwise as seen by the beam):

<u>Position</u>	<u>Contents</u>	<u>Purpose</u>
1.	Empty	
2.	Flag	used to view beam before extraction
3.	20 mil Cu wire	fully strip,multiple scatter and reduce intensity of 1 GeV/n Fe and Ti
4.	2 mil Cu wire	multiple scatter and reduce intensity of 0.3 GeV/n C
5.	5 mil W wire	fully strip, multiple scatter and reduce intensity of 1 GeV/n Fe and Ti
6.	0.7 mil W wire	multiple scatter and reduce intensity of 0.3 GeV/n C
7.	2 mil Cu foil	multiple scatter 0.3 GeV/n C
8.	20 mil Cu foil	strip and multiple scatter 1 GeV/n Fe and Ti

Once the beam is extracted it is directed out of the Booster tunnel into the NSRL beam transport line. The transport beam line consists of eight quadrupole magnets (Q1-8), two dipoles (D1-2), two octupoles (O1-2) and an assortment of small dipole correction magnets. A TRANSPORT (beam simulator) layout of the beam line is shown in Fig. 2 below with the predicted beam envelope for a small beam optics solution. The primary function of the first two quadrupoles, Q1-2, is to focus the beam through the 20 degree bend (D1-2) so as to emerge from the bend with no momentum dispersion in the

beam. Q3 and Q4 are then used to prepare the beam horizontal-vertical profile at O1 to maximize the effectiveness of this octupole to “gather-in” the wings of the horizontal beam distribution and transform the horizontal beam profile at the end of the beam line to approximate a rectangular distribution. Quadrupole Q5 does a similar tick to focus the beam horizontally into the second octupole to allow vertical beam profile manipulation by the second octupole (O2). Finally, Q6-8 are tuned to get the desired beam spot size in the target room. Five instrumentation packages are available to plunge into the beam at various locations in the beam line as needed to help align and focus the beam. See the NSRL web site for more details – <http://server.c-ad.bnl.gov/esfd/nsrl/index.html>. Rectangular uniform beam distributions with sizes ranging from 2 cm to over 20 cm on a side are possible. An example beam distributions are shown in Fig. 3.

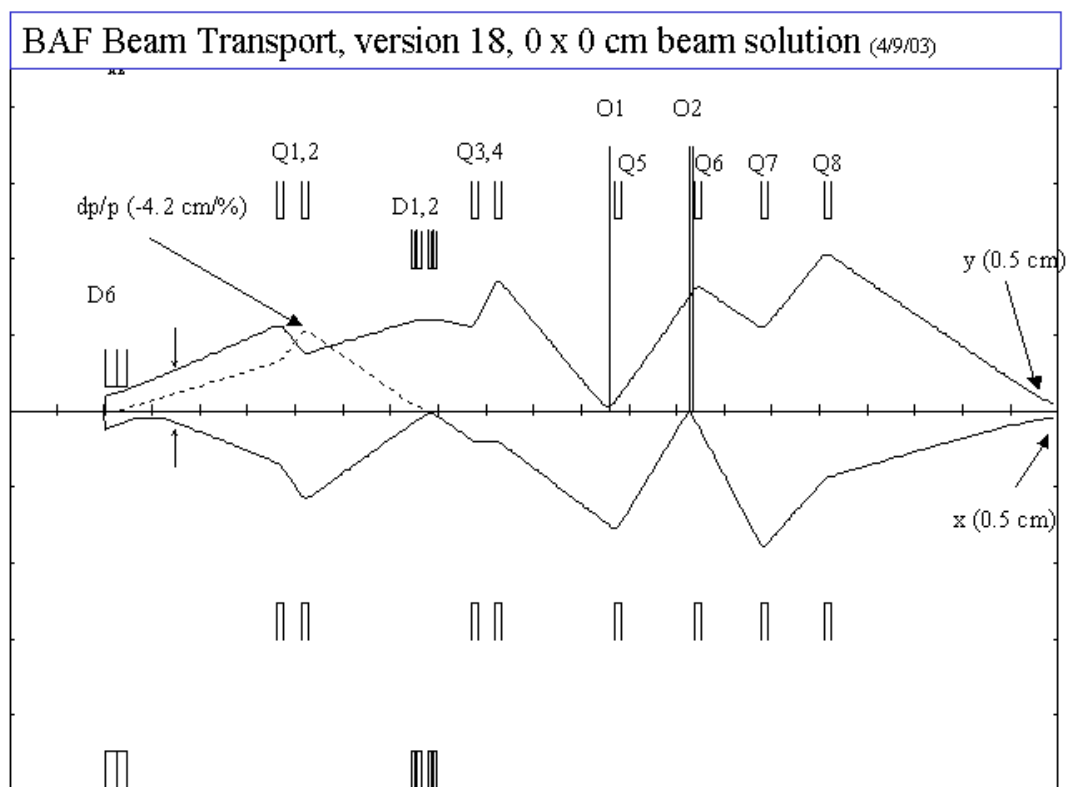


Fig. 2. Beam envelope as predicted by a TRANSPORT simulation – small beam solution.

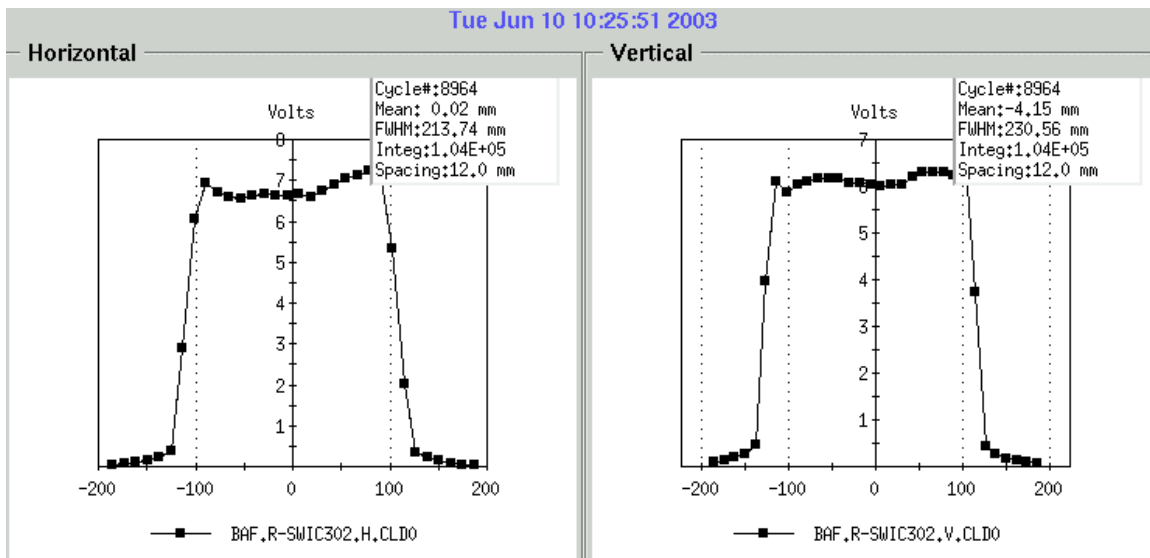


Fig. 3. Horizontal and vertical beam distributions at SWIC 302 (just upstream of target area) for a 300 MeV/n carbon beam.

Representative beams available at NSRL are listed below, along with energy ranges and maximum intensities.

Species	Charge State in Booster	Kinetic Energy (GeV/A)	Maximum Intensity (10^9 Ions/pulse)
p	1	0.73 – 3.07	100
^{12}C	6	0.09 – 1.23	2
^{28}Si	14	0.09 – 1.23	4
^{56}Fe	21	0.10 – 1.10	0.4
^{63}Cu	22	0.10 – 1.04	1
^{197}Au	32	0.04 – 0.30	2

At the time of the writing of this manual p (2 GeV), ^{12}C (290-300 MeV/n), ^{56}Fe (726 MeV/n), and ^{197}Au (112 MeV/n) beams have been extracted from the Booster.

As the intensity of the beams is measured in ions per unit of time, while the measure preferred by users of NSRL is the gray (Gy) per unit time, the reader will find the plot (Fig. 4) below useful. It gives the number of ions per cm^2 needed to deliver 1 Gy in water, as a function of beam energy per nucleon (MeV/n), for various species.

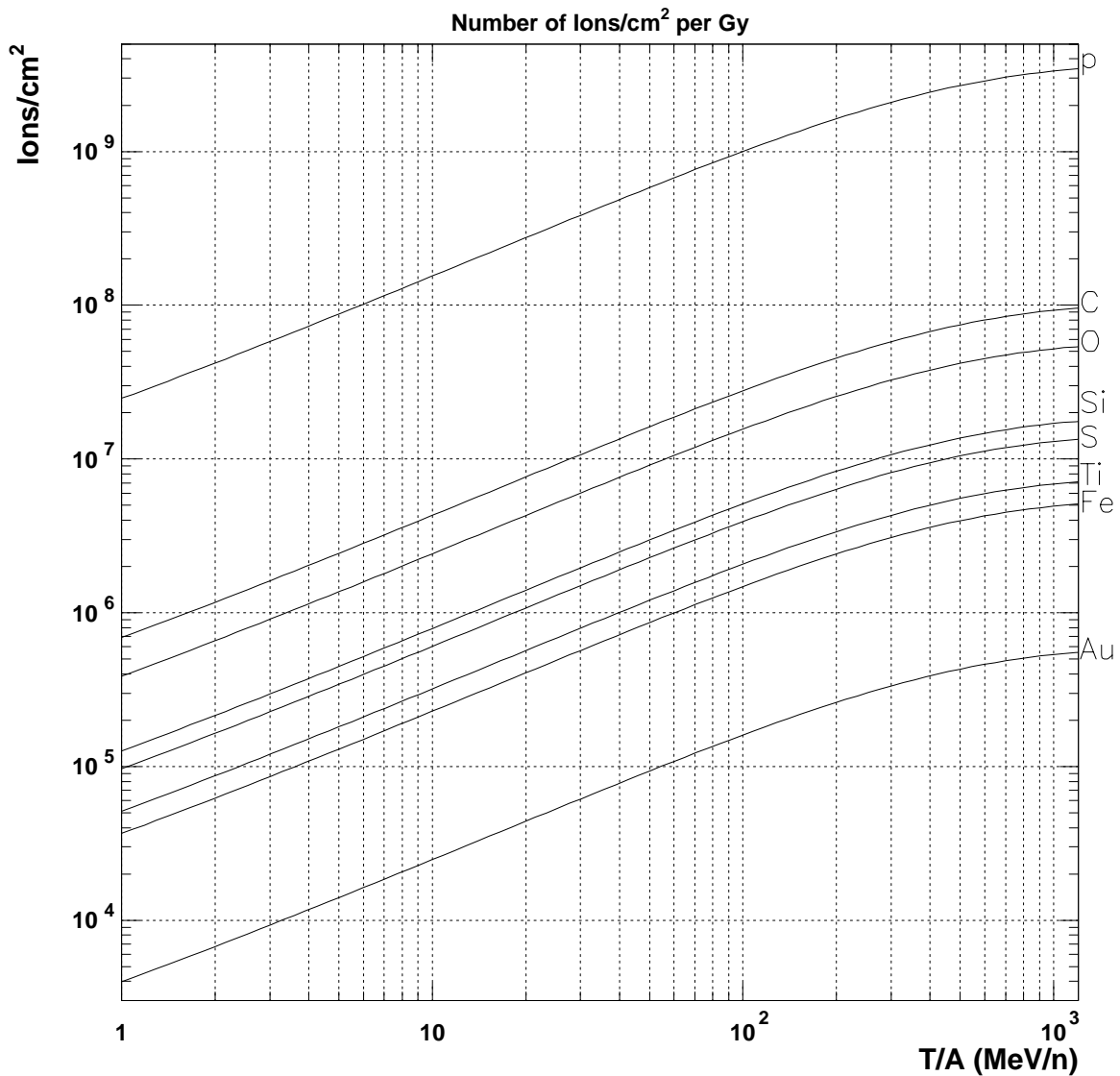


Fig. 4. Beam energy for various ions vs ions/cm²/Gy in water.

Instrumentation

The alignment benches are constructed of two parallel, 2-in.-diameter precision-ground steel rails, 20 feet long, separated by 15 in. between rail centers and mounted on a sturdy frame of welded channel iron. Beam center is 14 in. above the centerline of the rails. Preliminary alignment was done with surveying instruments. Final alignment of the bench is aided by use of segmented wire ion chambers (SWIC) at four critical positions in the beam transport system. The final SWIC is located just upstream of the optical

bench. The chamber in this final position has 2-mm wire spacing. Horizontal and vertical profiles of each beam pulse are displayed on monitor screens.

Ion Chambers

The basic ionization chamber used in biomedical dosimetry at NSRL consists of three foils (1 mil kapton with 200 Å Au on one side and 1 oz/ft² Cu on the other) mounted in a gas-tight aluminum housing. Two 1 mil thick Kapton H windows complete the gas (N₂) seal. The housing is square with an inner clear width of 39 cm, an outer width of 24 in., and a thickness of 4 cm.

The three foils are a 32-zone concentric-ring/quadrant foil, a high-voltage foil, and a 2- zone concentric-ringed foil. The ringed foil is constructed of a 3-mil Kapton H gold-plated membrane stretched and glued to a frame, then chemically etched on both sides. One side provides a pattern for electrical connections to various parts of the foil. The other provides various circular areas. The diameters of the concentric rings are as follows:

2,6,10,14,18,22,26, and 32 cm. Diameter. (32-zone side)

There are three such chambers on the target bench. A fourth chamber is located just downstream of the target area. Its foil is divided into 256 square elements, 1.5 cm each, Arranged in a 16x16 element array.

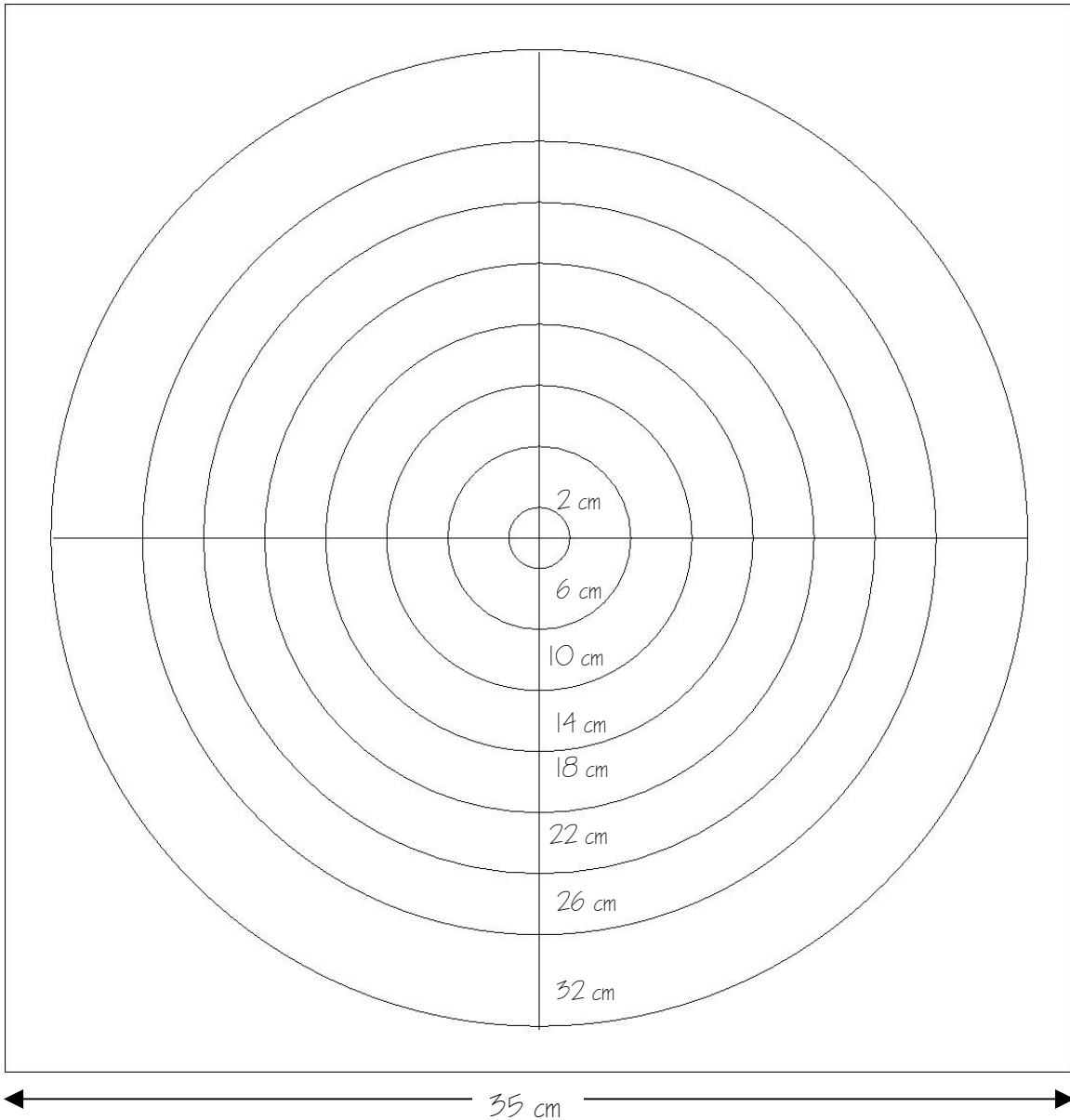
The high-voltage foil is a double gold-coated, 3-mil Kapton H foil. It is sandwiched between two rings and constructed to eliminate high electrostatic fields in the gas at the edge of the high-voltage foil.

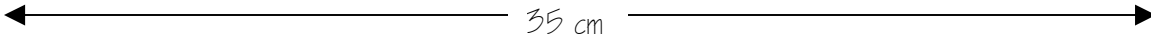
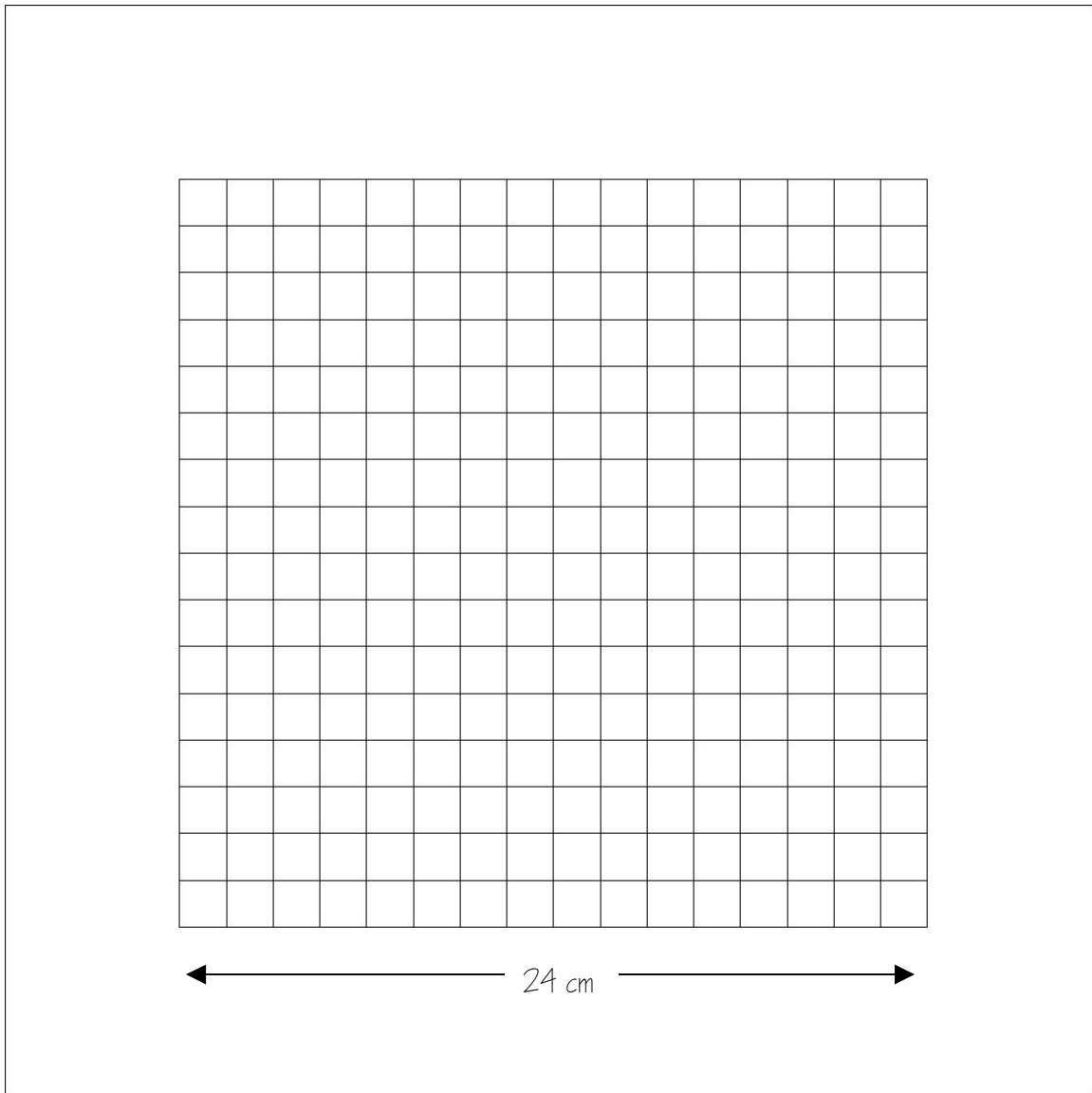
The separation between each outer foil and the inner high-voltage foil is 1.3 cm. The ringed foil is both a beam-distribution-sensing device and a dose-measuring device, while the quadrant foil is primarily for beam positioning and sensing.

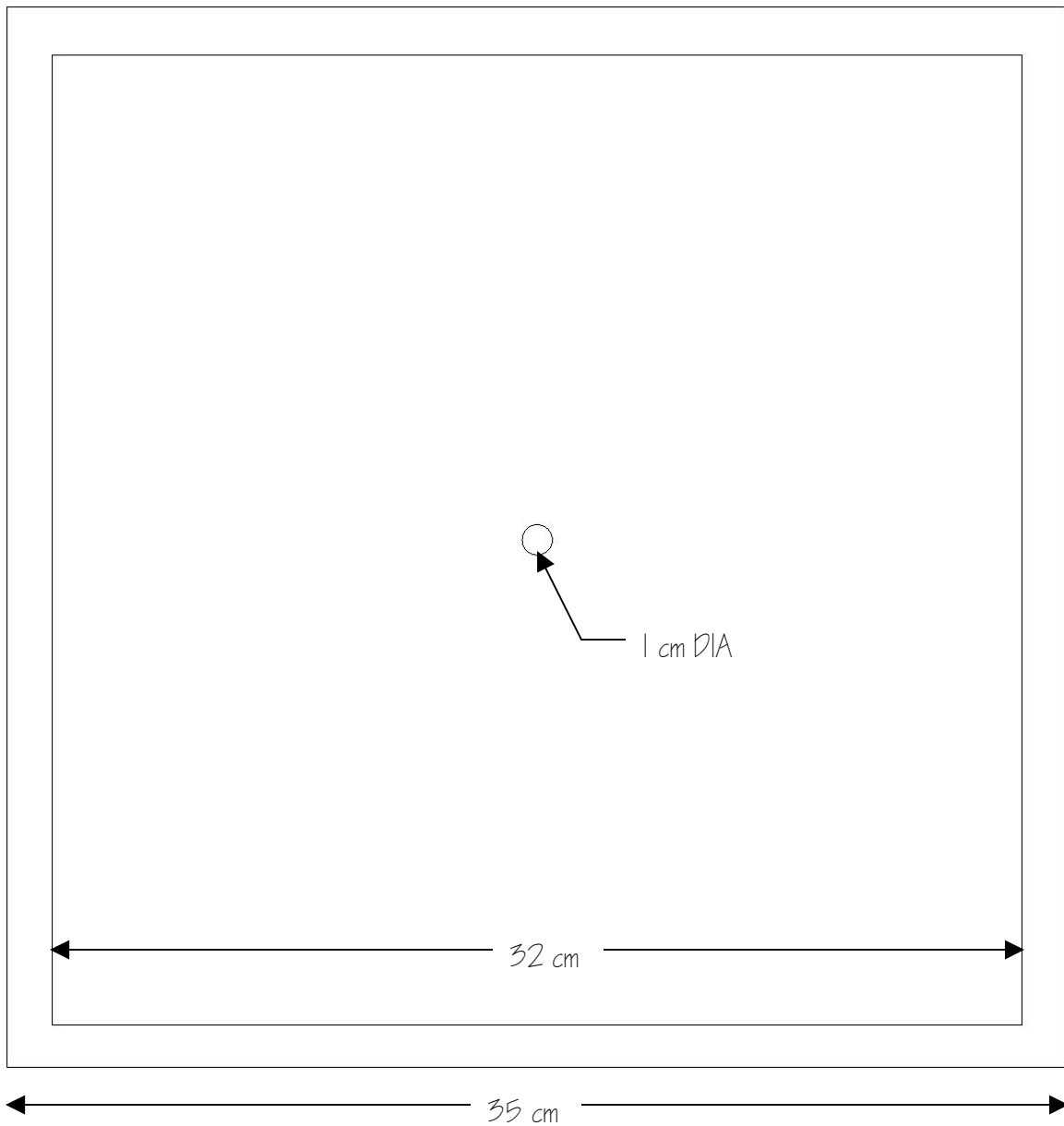
The chamber is flushed with dry nitrogen gas, in most cases with a low flow rate (0.01 ft.3/h) and a minute overpressure generated by a gas bubbler connected to the exit gas port on the chamber. Each collecting electrode is connected to a recycling integrator channel located in the [physics room](#). These are a modification of a LLNL design and have a conversion constant of 1 count/10⁻¹¹ coulombs. They are linear over about seven decades of current, with maximum current of approximately 7 x 10⁻⁶ A. The outputs of the recycling integrators are connected to scalers on the same board. The scalers are interrogated by the computer before and after each beam pulse. The counts are added to the previously accumulated counts. A background count correction is made.

While any combination of areas may be selected for determining the dose that was delivered to the sample, the actual dose cutoff is determined from the charge collected from the central 2-cm diameter circle. The basic calibration factors for each collecting area are determined by the area of the collecting electrode and its separation

from the high-voltage electrode. Until values of W have been determined, we assume a value of 34.9 eV/ip for heavy ions in nitrogen gas. The other assumption we have made is a value of 1.125 for the relative mass stopping power of water to nitrogen. A Far West thimble chamber with its associated secondary National Bureau of Standards (NBS) calibration is used for the primary dose calibration. This type of chamber is commonly referred to as an egg chamber.







Binary Filter (variable thickness polyethylene)

The binary-filter absorber can vary the range (energy) of the particles striking a target by introducing a measured amount of polyethylene (CH_2) into the beam path. The absorber consists of 9 individual polyethylene sheets ranging in thickness from 0.05 cm to 12.8 cm. Thickness is controlled by computer insertion of the appropriate combination of sheets and can vary from 0 to 25.55 cm in .05 cm steps. The binary-filter is left on the bench. An example Bragg curve is shown in Fig 5 below. This was generated using a 280 MeV/n carbon beam.

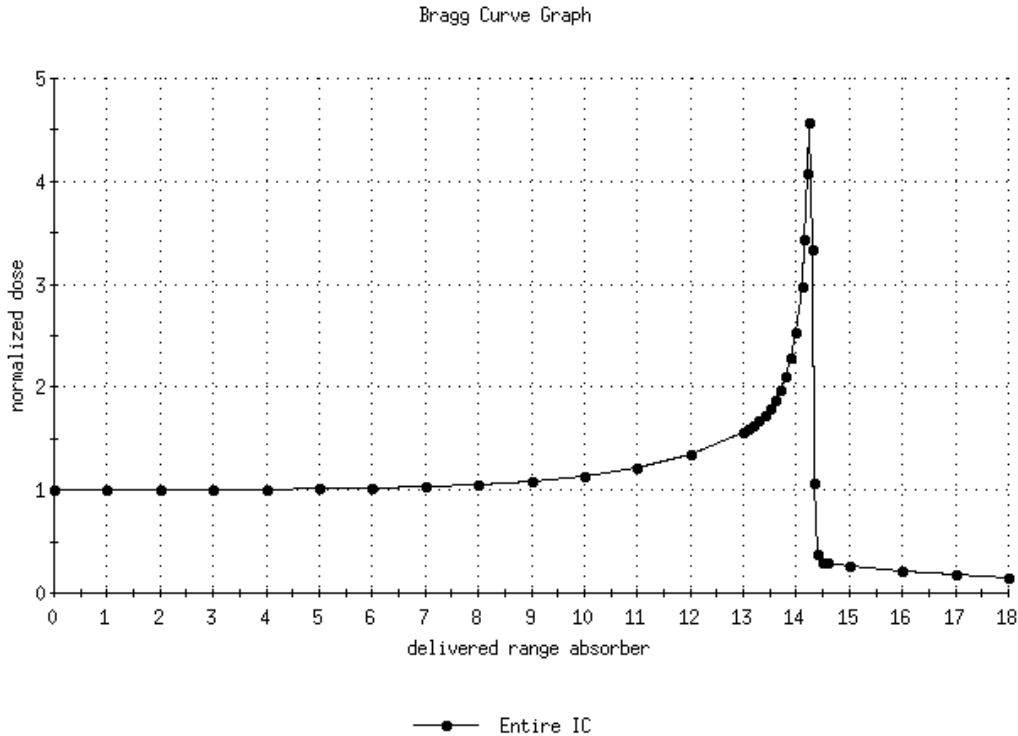


Fig. 5. Measured range (cm) of 280 MeV/n carbon in CH₂ binary filter.

A list of materials upstream of the binary filter array in order as seen by the beam follows:

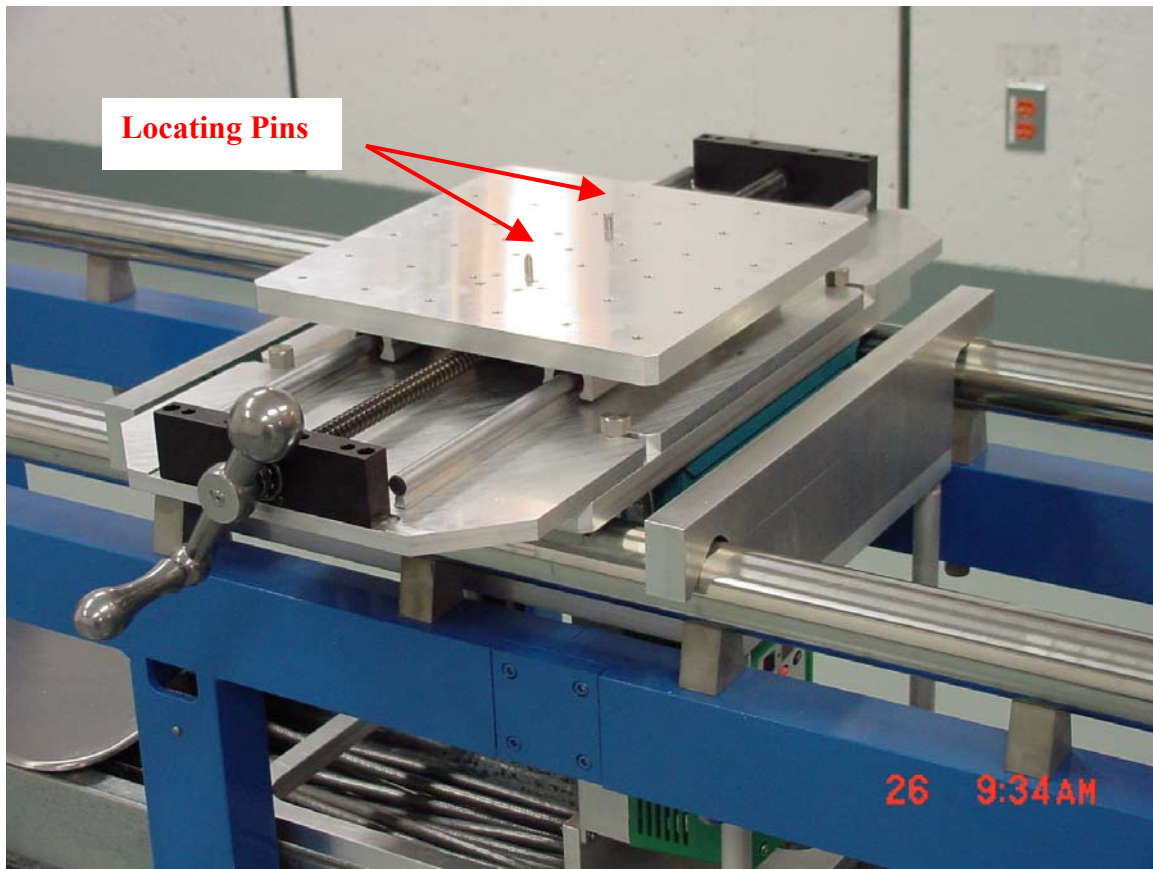
- 1) Vacuum window: 15 mils Aluminum
- 2) Air: 50.8 cm
- 3) R300 Flag, Radlin; 40% Cd, 60% ZnS - (few mils) on plastic substrate, 31 mils total (normally plunged out of beam)
- 4) Air: 44.4 cm
- 5) R302 SWIC and Ion Chamber: (normally be plunged out of beam)
 - a. 5.5 mil Al
 - b. 10 Mil kapton
 - c. 20 cm Ar/CO₂ (50%/50%)
 - d. SWIC wires: 96 tungsten (with 3% rhenium and 0.7 mil Au plate) wires in each plane (X/Y) spaced 4 mm apart wired together in groups of 3 to give 1.2 cm resolution.
- 6) Air: 330 cm (nominal drift, depends on exact location of First ion chamber)
- 7) First Ion Chamber in Dosimetry package

- a. 5 mil kapton
 - b. 0.061 g/cm² copper
 - c. 400 Å gold
 - d. 4 cm Nitrogen gas
- 8) Air: 11.4 cm (nominal)
- 9) Binary Filter
- 10) Second Ion Chamber in Dosimetry package
- a. 5 mil kapton
 - b. 0.061 g/cm² copper
 - c. 400 Å gold
 - d. 4 cm Nitrogen gas
- 11) Third Ion Chamber in Dosimetry package
- a. 5 mil kapton
 - b. 0.061 g/cm² copper
 - c. 400 Å gold
 - d. 4 cm Nitrogen gas
- 12) Radiobiology samples
- 13) Fourth Ion Chamber in Dosimetry package (256 channels)
- a. 5 mil kapton
 - b. 0.061 g/cm² copper
 - c. 400 Å gold
 - d. 4 cm Nitrogen gas

Sample Holders

There are currently no sample holders available at NSRL. To date, during the eight AGS runs the users have supplied the sample holders, all made to mount on the target translator, which is a lift and lateral movement stage. The lift is achieved by means of an electric motor, while the translation is manual. The table top is fitted with a set of threaded holes (1/4"-20) and two locating pins (1/4", 4" apart). A photo of the table is shown below.

We expect to start developing standardized sample holders once we gain experience with the particular positioning challenges associated with the field.



The lift and translator. The lift is by motor, with a 10" travel and a 500lb capacity. The translation travel is +/- 6". The locating pins pattern is identical to that used in the AGS A-line cave, and has become somewhat of an "industry standard".

Special Experimental Conditions

Each experiment is unique in its design and objectives. Any exceptional requirements for equipment and/or data acquisition should be discussed well in advance with the NSRL liaison physicist (631-344-5830). Suggestions for new standard equipment desired for general use should also be conveyed to him.

Setting Up Your Experiment in the Target Room

Once an experiment is approved and scheduled, the experimenter should discuss with the NSRL liaison physicist (ext. 5830) any physical problem associated with placing the samples in the beam. Experimenters are encouraged to visit NSRL in advance to work out details of experiment protocol. If this proves impossible, complete drawings and/or photos of the experimental apparatus or samples should be sent to the NSRL liaison physicist as far in advance as possible. A picture taken inside the target room is shown in Fig. 6 below.

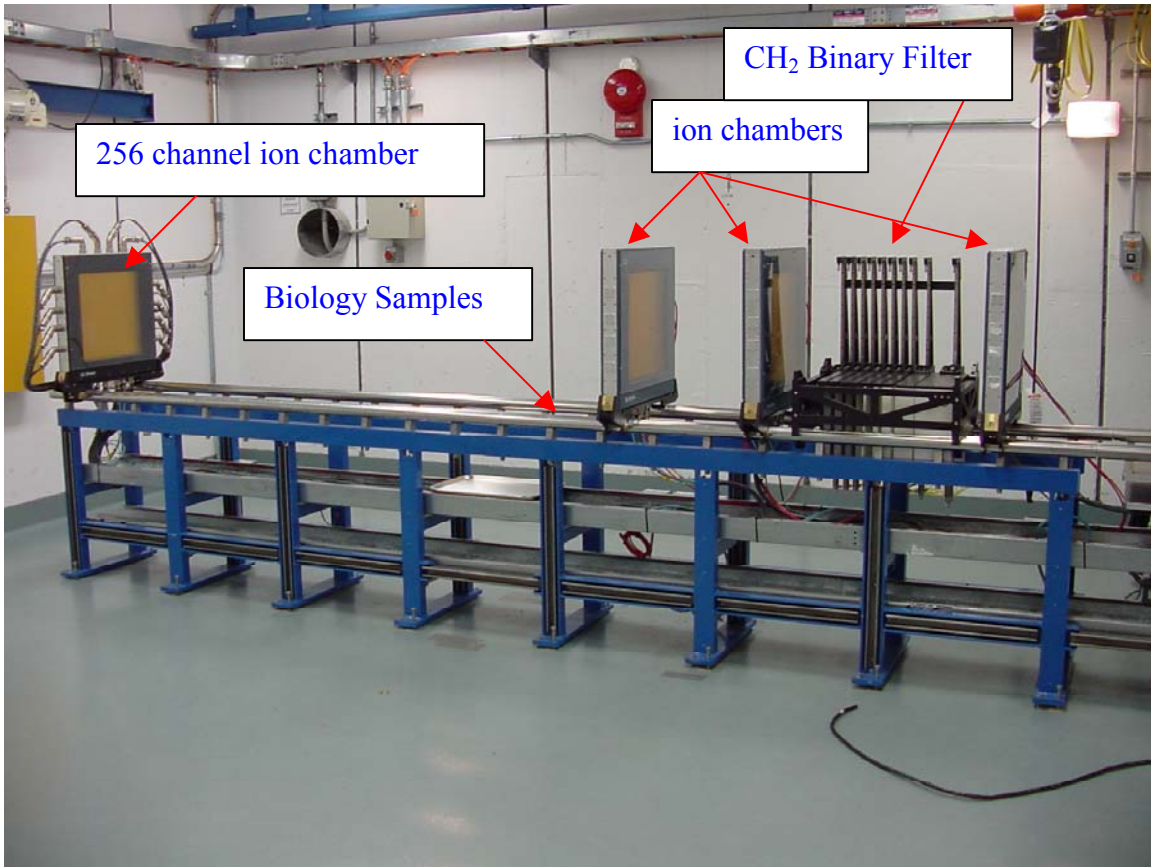


Fig. 6. NSRL target room

Access to Target Room

Each person entering the target room during a run has primary responsibility for his or her own safety. A picture of the NSRL target room access system is shown in Fig. 7. Access to the target area is gained through the use of a card reader or iris-scanner/token-key depending on the operational state of the beam line. Only properly trained individuals can access this area. There are two modes of access defined as, “Restricted” or “Controlled”.

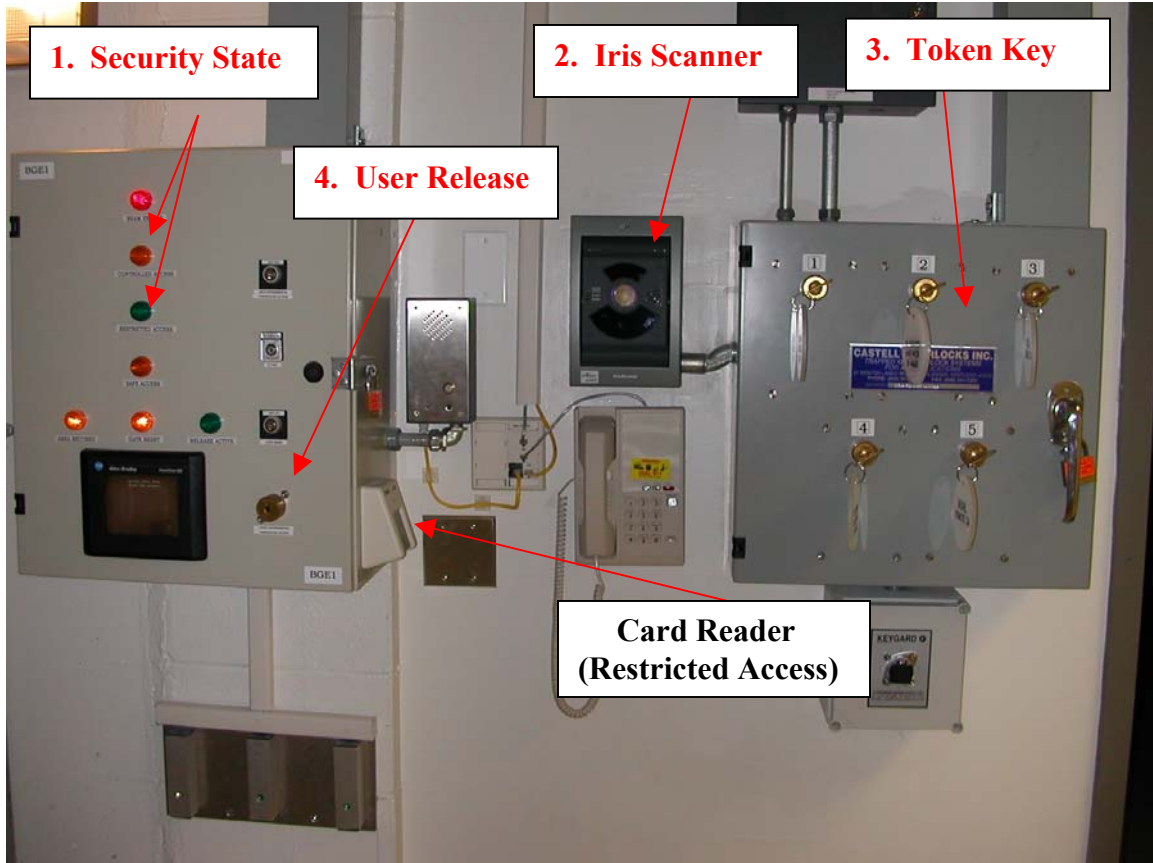


Fig. 7. Picture of the NSRL target area access system.

Restricted Access

When the target room is in a “Restricted Access” state (green state-light), the doors to the target room will open with a placement of an orange access card on the card reader. This is the normal state of the system when beam is not being used for Radiobiology experiments.

Controlled Access

When the target room is in a “Controlled Access” state (orange state-light), access is granted only to those with [appropriate training](#), and with a simultaneous release of interlocks, by both user and Main Control (MC). This mode is the usual mode of access during radiobiology runs. The beam is momentarily interrupted while the access is made then returned once the access is complete. The verification-of-training is achieved by the iris-scanner, which, upon recognition, will display the user’s name in the control room

(this allows the MC operator to write down the user's name in the log sheet), and will release one of the token-keys to the user. The key is then inserted into the key release (number 4. in Fig. 7).

Emergency Procedures

The emergency procedure for the NASA Space Radiation Laboratory, [Emergency Procedure for Building 958, NASA Space Radiation Laboratory OPM 3.25](#), is intended to provide general guidance for responding to most incidents that may occur at the facility. The emergency procedure supplements the [Local Emergency Plan for the C-A Department OPM 3.0](#) and takes into account the special conditions that exist at NSRL.

Environmental Training

A training package ([NASA Space Radiation Laboratory Environmental Training](#)) has been designed to aid in the delivery of job-specific training for C-AD staff who may work at the NSRL. Some of the information also applies to NSRL Users. This package is brief and provides Users with information the following environmental aspects associated with the facility:

- Regulated Medical Waste generation
- Atmospheric discharges
- Liquid discharges
- Soil activation
- Storage/use of radioactive material

This is not a required course and Users do not have to submit the associated Read and Acknowledgement form.

Appendix A

TERMS AND CALCULATIONS

A. TERMS

1. Bragg Curve

The Bragg curve is obtained by placing ion chambers on each side of the CH₂ binary filter. An egg chamber can be placed behind a transmission chamber or in a water phantom. The routine selects a fixed cutoff on the upstream chamber and normalizes the readings from the downstream chambers to the upstream chamber and to the first point taken. Certain elements are displayed on the terminal but a much larger choice of printouts is available. The two usual choices are the ratios from the 1-cm element of the dose chamber and/or all the elements from the dose chamber.

The 1-cm element is desirable for small samples and when there is sufficient beam current for adequate statistics. The sum of the rings from the dose chamber is appropriate to large samples and/or low beam currents. One can improve statistics for the 1-cm area by taking more pulses or a higher dose cutoff, but this may consume expensive amounts of beam time. Usually one Bragg curve per new experiment is sufficient. The range for a given energy is usually constant unless there have been changes made in the beam line. This is checked frequently and a curve does not need to be run for every experiment if each one is using the same energy and tune.

At present, all of the curves generated from the individual rings of the dose chamber, with the exception of their sum, are normalized to the 1-cm area of the monitor chamber. The sum of the rings is normalized to the sum of the rings of the monitor chamber.

2. Collimation

A standard set of collimators is not available at this time for NSRL users. If special collimation is required arrangements should be made well in advance with the NSRL Liaison Scientist, (631) 344-5830 or rusek@bnl.gov.

3. Egg Chambers

Egg chambers (Far West) are special ionization chambers having different geometry than the transmission chambers. They generally are available in two volumes, 1.0 cc and 0.1 cc. They are used in several ways. They are used as the main calibration of dose to the sample and the transmission chamber is used merely to monitor and deliver so many units based upon the egg reading in a simulated set up. They are also used to determine the dose fall off or buildup to the sample when the transmission chamber cannot either be placed in close proximity to the sample during irradiation or at anytime prior to irradiation. The method of choice, when it can be done, is to move the dose chamber in place of the sample and take a ratio between the two positions relative to the

monitor chamber (IC1) or backup chamber (IC2). In lieu of this, one can use the calibration of the egg chamber to determine the dose in awkward situations. Another use of the egg chambers is to cross check the calibration of the dose chamber. A fourth use is when one wants to measure a depth-dose curve in specialized water phantoms.

4. Units

Dose is expressed in rads, which is a unit of absorbed dose. It is "the amount of energy imparted to matter by ionizing particles per unit mass of irradiated material at the place of interest." Its units are 100 ergs per gm. The SI unit for absorbed dose is the gray (Gy), where 1 Gy = 100 rad.

B. CALCULATIONS

1. Converting Dose to Particles/cm²

$$n(r) = \text{number of particles/cm}^2/\text{Gy}$$

For Water:

$$n(r) = 6.242 \times 10^9 / dE/dx \quad (\text{Mev/cm})$$

$$n(r) = 6.242 \times 10^8 / \text{LET} \quad (\text{keV/um})$$

Example:

To convert 1 Gy of iron particles at 600 MeV/n. The LET for this ion in water is 1740 MeV/cm, so substituting:

$$n(r) = \frac{(6.242 \times 10^9)}{1740} = 3.6 \times 10^6 \text{ particles/cm}^2 \text{ per Gy}$$

A handy on-line (as well as a personal downloadable version) calculator for LET and range for ions in various materials can be found at <http://tvdg10.phy.bnl.gov/index.html>.

Appendix B

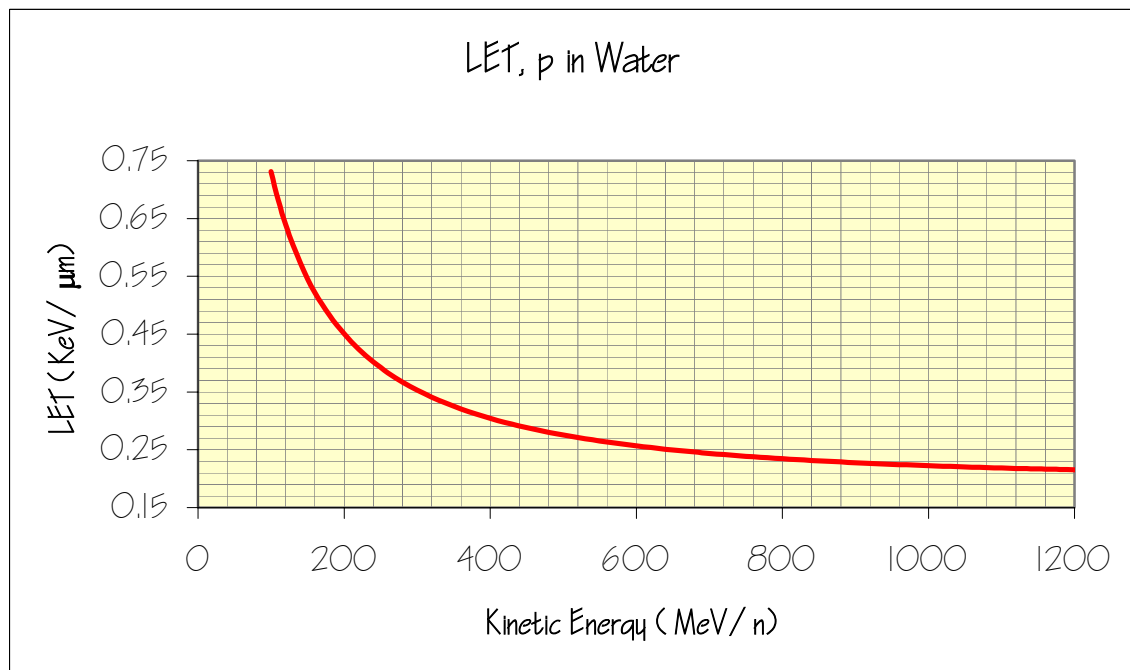
Plots

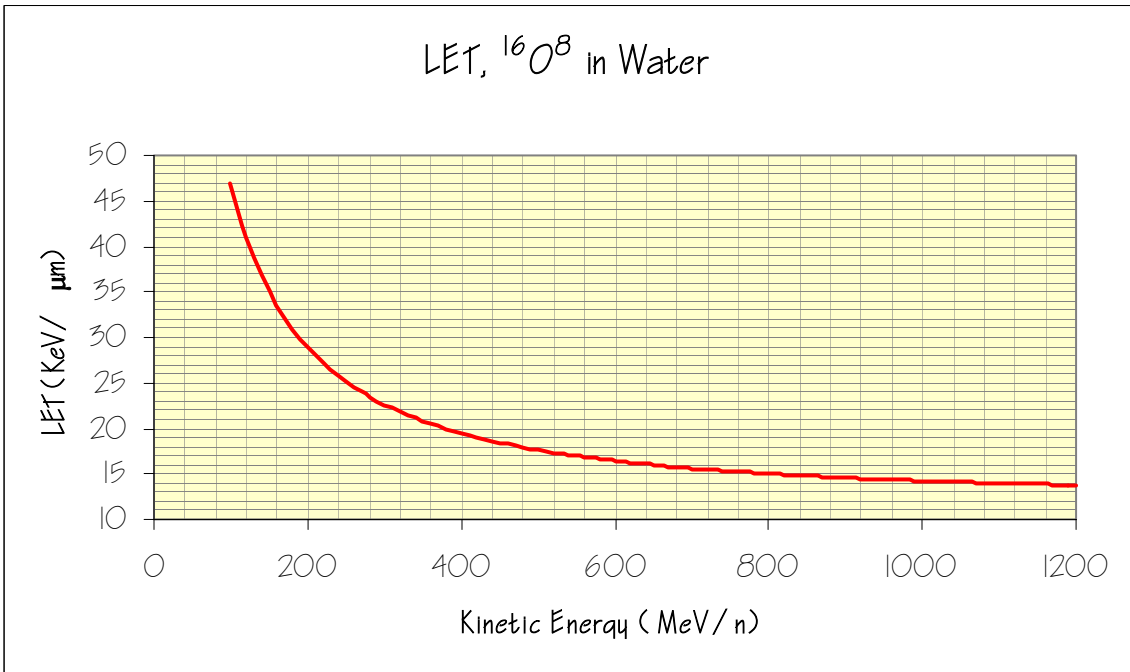
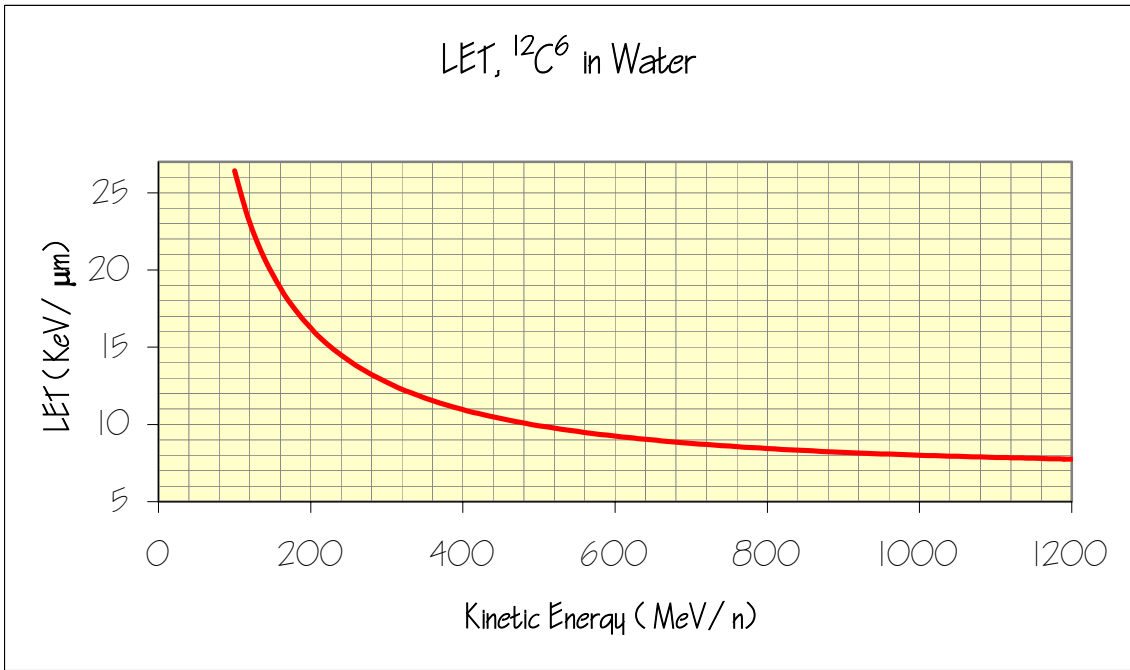
The following plots relate the linear-energy-transfer (LET) in *water*, in KeV/ μm , to the kinetic energy per nucleon for several ions, one plot each. The KeV/ μm is the unit of choice of radiobiologists, while physicist prefer the MeV/cm, or the MeV/(g/cm²).

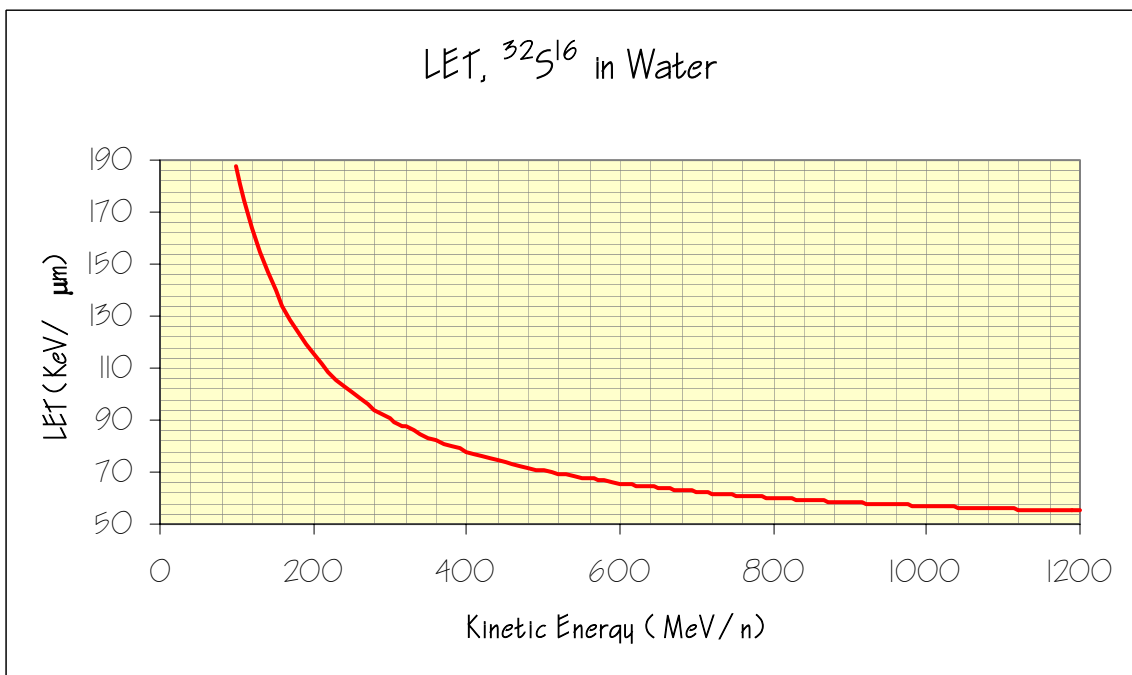
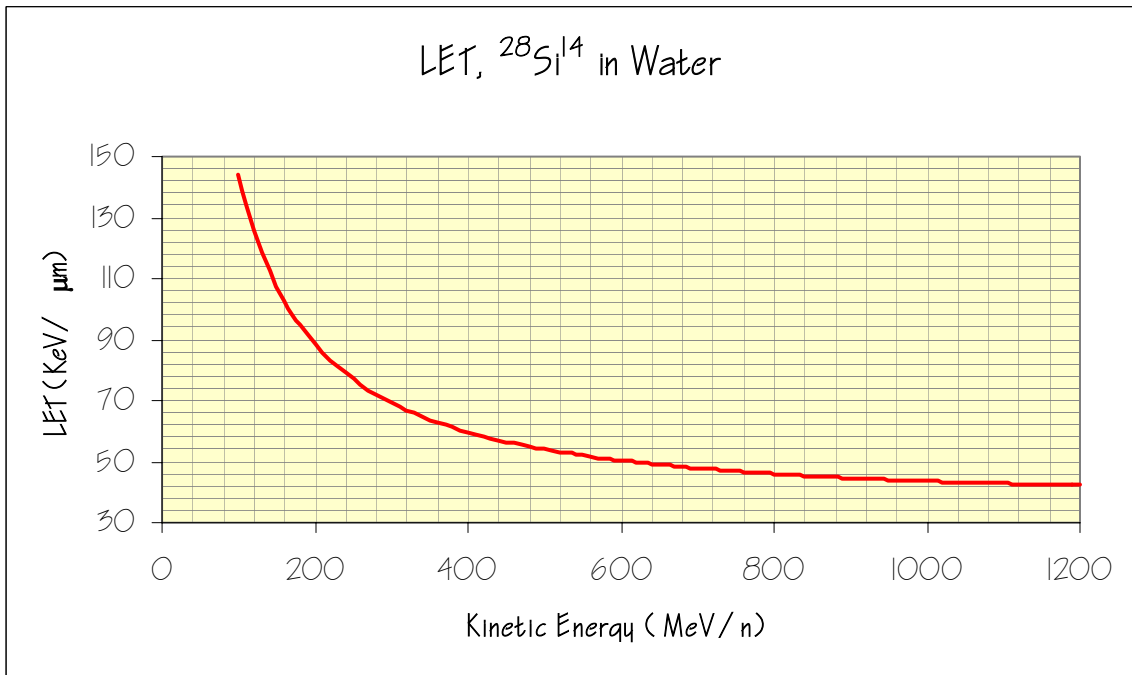
$$1 \frac{\text{KeV}}{\mu\text{m}} = 10 \frac{\text{MeV}}{\text{cm}} = 10 \frac{\text{MeV}}{\text{g/cm}^2}$$

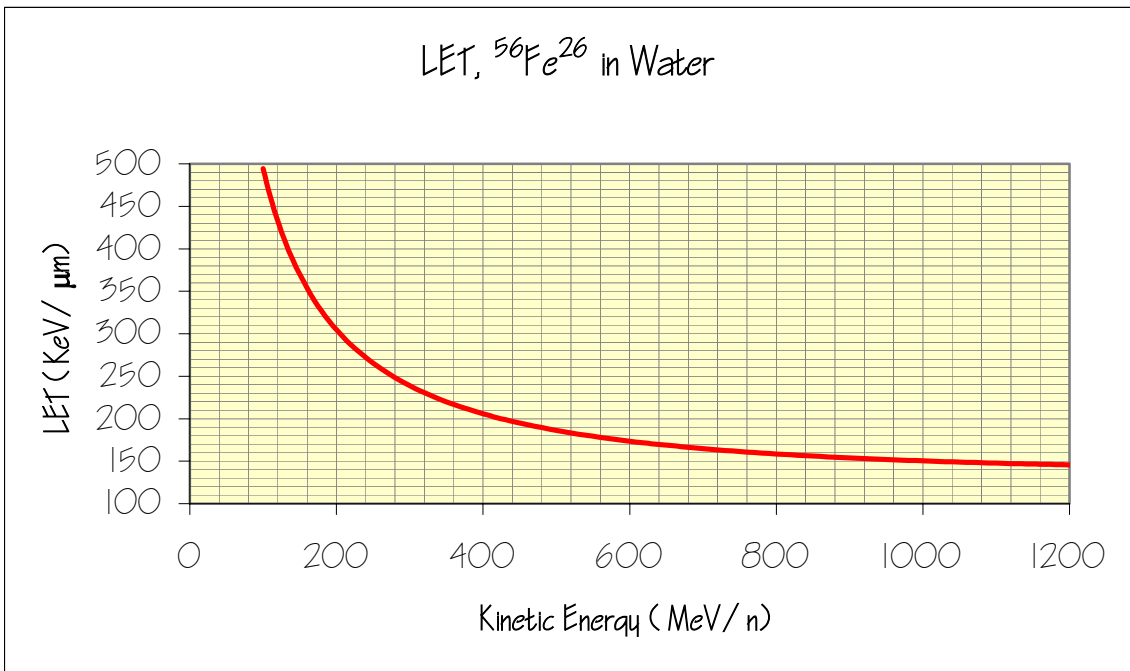
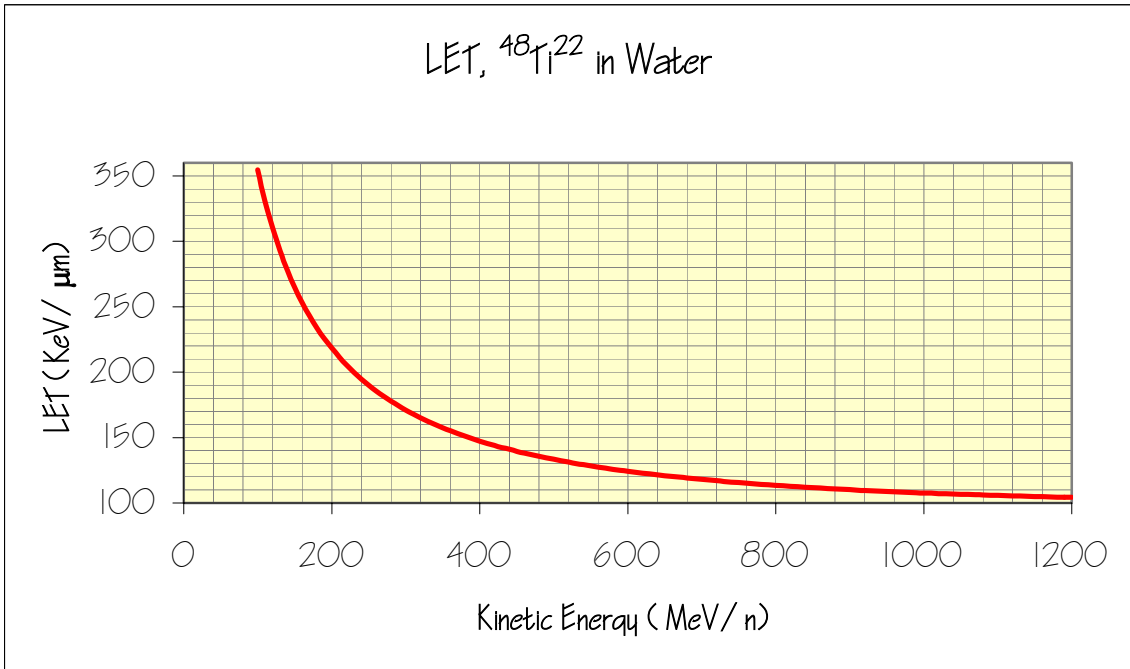
For Water ($\rho = 1 \text{ g/cm}^3$)

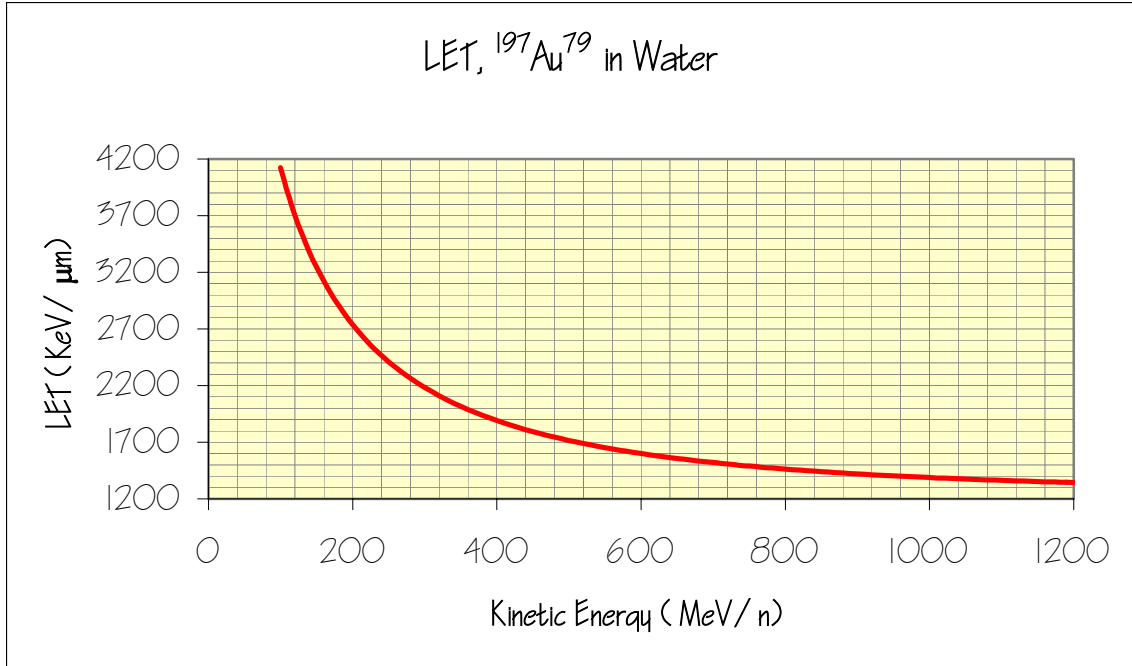
At this time, plots are given for protons, C, Ti, Fe and Au. More will be added later.

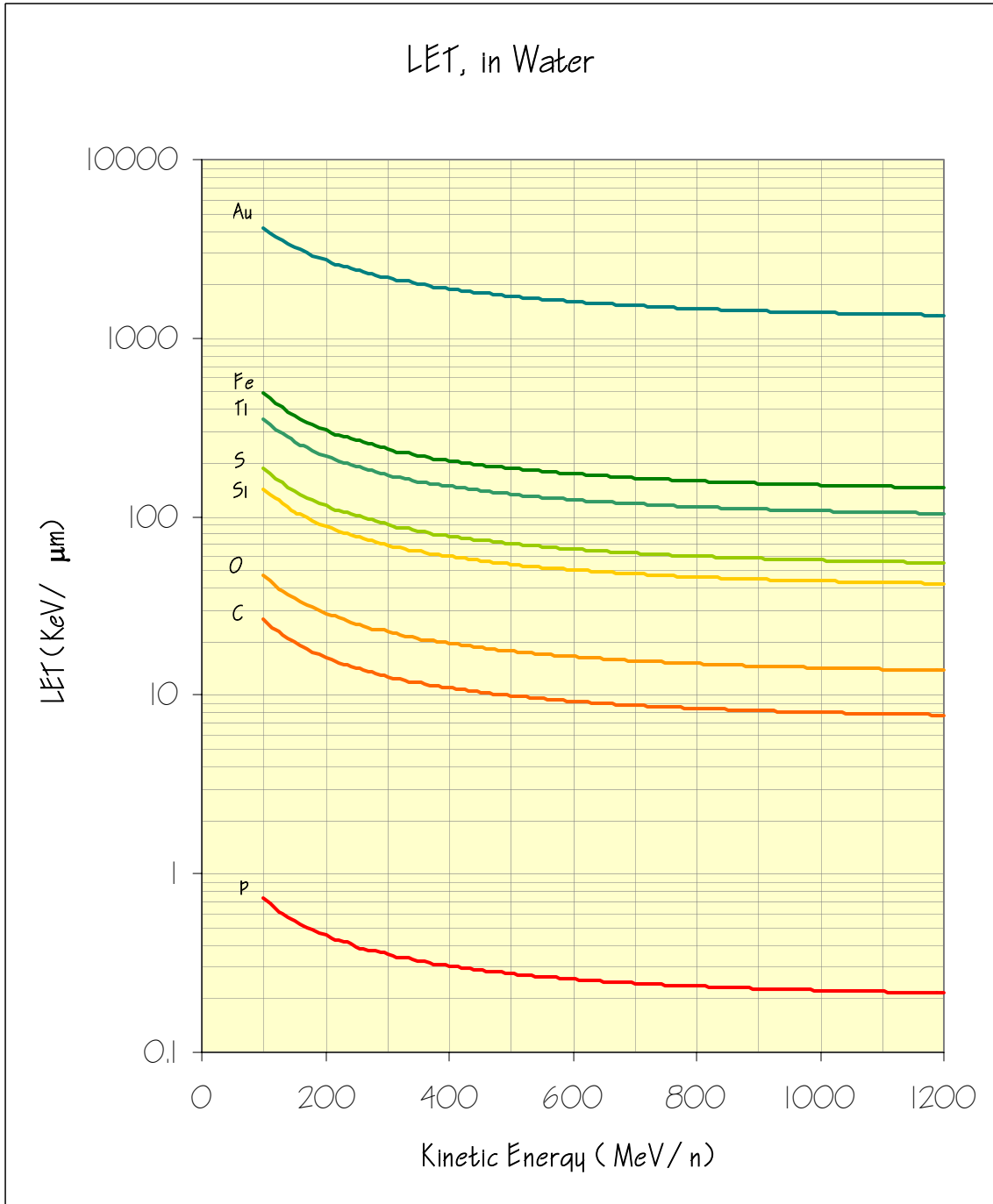




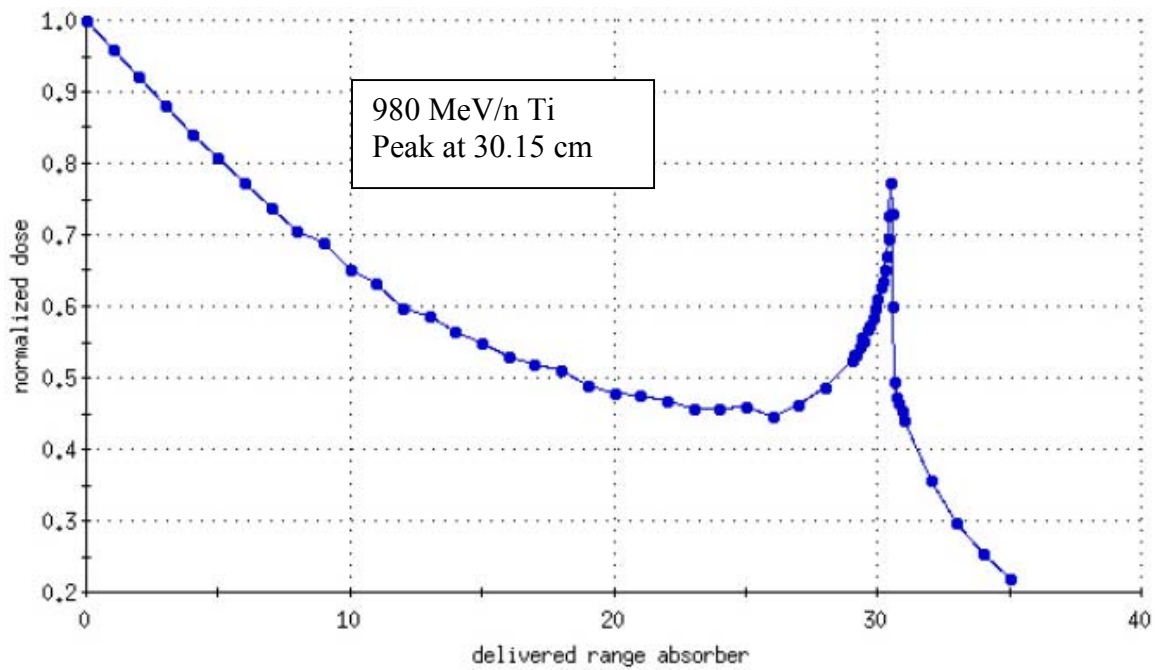
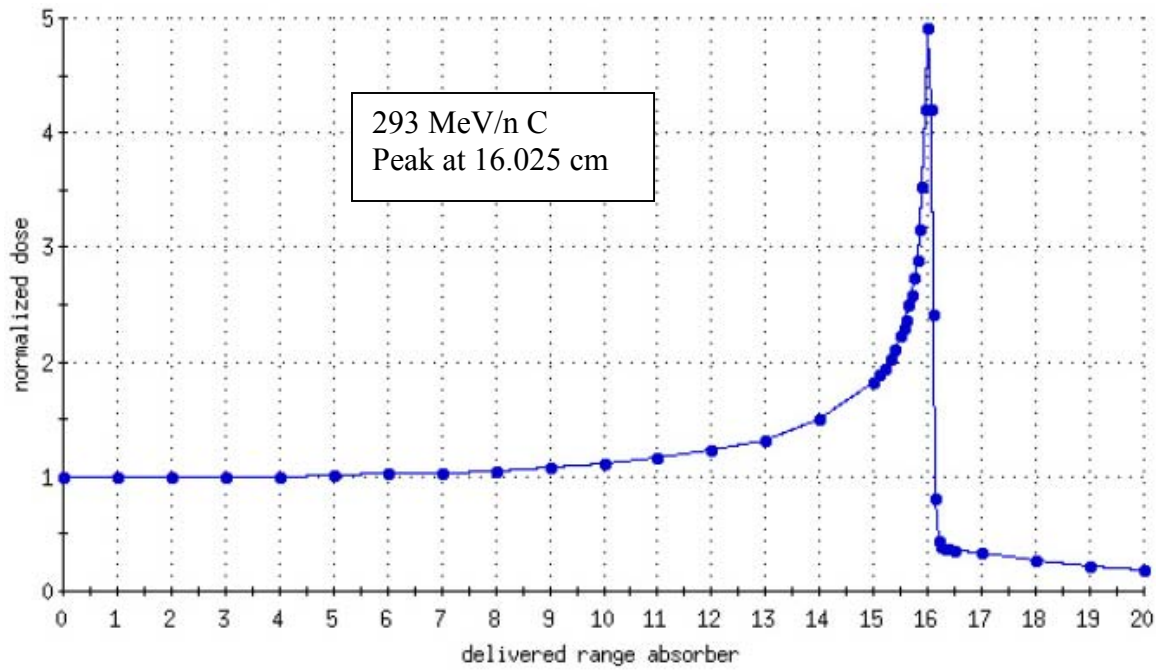


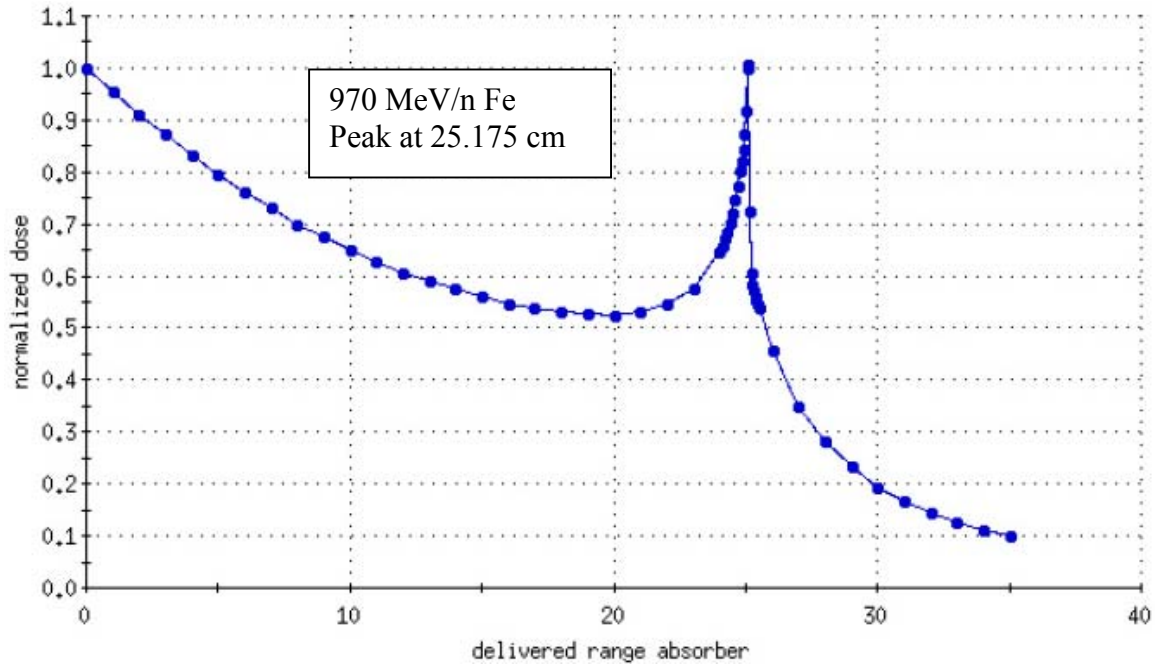






Bragg Curves





Appendix C

Ions Extracted into NSRL During Runs 0 and 1

Listed below are the ions extracted and used for biology experiments at NSRL so far. Maximum intensity and dose-rate are shown only. To achieve lower dose-rates, we use the two-jaw collimator at the extraction to reduce the beam flux without changing its shape. Changing the beam size changes the dose-rate, but beware: the dose-rate are measured at the center of the ion-chamber, and only scales roughly with area.

Energy at extraction is deduced from frequency measurements in the Booster. Energy at the NSRL target area is obtained from Bragg-curve measurements (done daily during the run).

The LET given here is that for the primary ion at the “on target” energy, in water.

Beam sizes for the biology experiments are the “useful” sizes, defined on the last page.

Spill period can stay short, around 3 second, as long as NSRL is running alone, without RHIC. Otherwise, when using PPM (**p**ulse to **p**ulse **m**odulation), during which each super-cycle can deliver either a RHIC puls, an NSRL pulse or BOTH, the length of the period becomes about 6 seconds (for example, see the C run below)

List of Ions (Biology) as Recorded During NSRL-1:

Fe: Extraction Energy: 1005 MeV/n
 Target Room Energy: 970 MeV/n
 LET_{water} : 151.3 MeV/μm
 Maximum intensity: 1.0×10^9 Fe/spill
 Spill Length: 400 msec
 Spill Period : 3.0 sec

Beam Size (cm × cm)	Dose Rate at maximum intensity (Gy/min)
20 × 20	7.0
10 × 10	30.0
7 × 7	70.0
7 × 30	12.0

Ti: Extraction Energy: 1007 MeV/n
 Target Room Energy: 980 MeV/n
 LET_{water} : 108.1 MeV/μm
 Maximum intensity: 4.0×10^8 Ti/spill
 Spill Length: 400 msec
 Spill Period : 3.0 sec

Beam Size (cm × cm)	Dose Rate at maximum intensity (Gy/min)
20 × 20	2.5
10 × 10	10.0
7 × 7	20.0
7 × 30	4.0

C: Extraction Energy: 300 MeV/n
 Target Room Energy: 293 MeV/n
 LET_{water} : 12.88 MeV/μm
 Maximum intensity: 1.2×10^{10} C/spill
 Spill Length: 400 msec
 Spill Period : 5.4 sec

Beam Size (cm × cm)	Dose Rate at maximum intensity (Gy/min)
20 × 20	4.0
10 × 10	10.0
7 × 7	20.0

Projected for NSRL-2:

Fe: Extraction Energy: 600 MeV/n
 Target Room Energy: 583 MeV/n
 LET_{water} : 175.4 MeV/μm
 Maximum intensity: 1.0×10^9 Fe/spill
 Spill Length: 400 msec
 Spill Period : 3.0 sec

Beam Size (cm × cm)	Dose Rate at maximum intensity (Gy/min)
20 × 20	7.0
10 × 10	30.0
7 × 7	70.0

Si: Extraction Energy: 600 MeV/n
 Target Room Energy: 586 MeV/n
 LET_{water} : 50.8 MeV/μm
 Maximum intensity: $?.? \times 10^7$ Si/spill
 Spill Length: 400 msec
 Spill Period : 6.0 sec

Beam Size (cm × cm)	Dose Rate at maximum intensity (Gy/min)
20 × 20	?
10 × 10	?
7 × 7	?

C: Extraction Energy:	300 MeV/n
Target Room Energy:	293 MeV/n
LET _{water} :	12.88 MeV/ μ m
Maximum intensity:	1.2×10^{10} Si/spill
Spill Length:	400 msec
Spill Period :	6.0 sec

Beam Size (cm \times cm)	Dose Rate at maximum intensity (Gy/min)
20 \times 20	3.6
10 \times 10	9.0
7 \times 7	18.0

List of Ions (Physics):

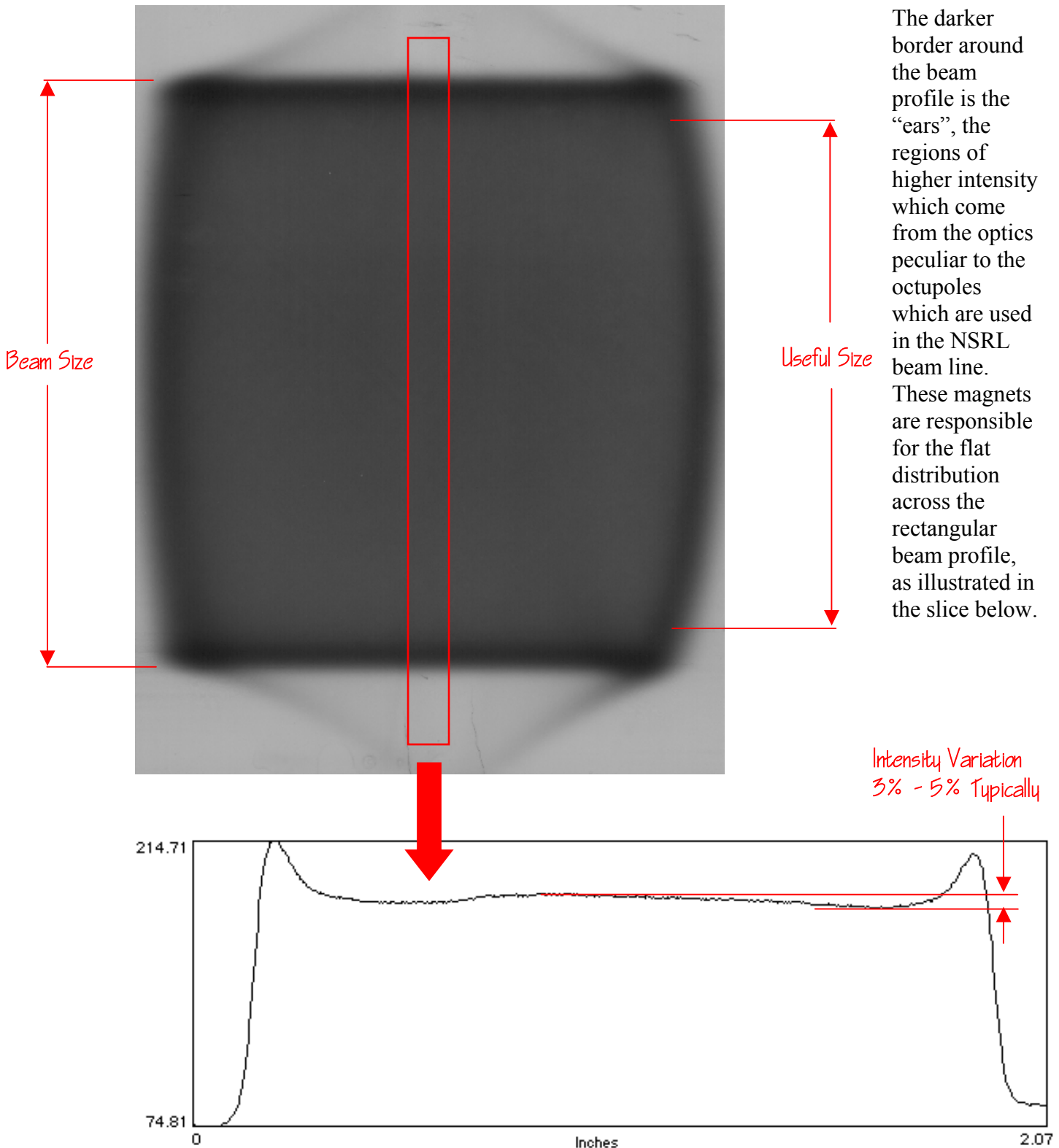
In this mode, the beam is tuned with a round profile and is typically small, around 1-2 cm in diameter. Spill structure can be reduced greatly with about $\frac{1}{2}$ - 1 hour of expert effort. Rates can be brought down to several hundred counts per spill, with higher rates easily achievable. Under these conditions, we have extracted the ions listed below at the corresponding energies:

Fe: 1000, 800 MeV/n
 Ti: 1000 MeV/n
 C: 300 MeV/n

Low Dose-Rate Biology:

For those biology experiments requiring low dose rates (typically the dose will be specified in counts per square cm, *ie.* 500 Fe/cm²), we can tune the beam down to a rate of several hundred per square cm per spill. Beam shape is difficult to monitor at this rate and at this time (a counter capable of doing both dosimetry and beam profile at these rates will be available soon), but we do have a scintillation counter based cutoff system which does a good job (within 3%). We have done low dose rate experiments with all ions listed for biology above.

Shown below is a scanned image of the Ti beam used during NSRL 0, as recorded on an x-ray film. The approximate size of the beam was 20x20 cm² (about 18x18 cm² useful area).



The darker border around the beam profile is the "ears", the regions of higher intensity which come from the optics peculiar to the octupoles which are used in the NSRL beam line. These magnets are responsible for the flat distribution across the rectangular beam profile, as illustrated in the slice below.