

BROOKHAVEN NATIONAL LABORATORY

BIOLOGY DEPARTMENT

BNL-5 RUN

FINAL REPORT

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EXECUTIVE SUMMARY

During the spring of 1999, a series of radiobiological and physics experiments were performed using the BNL's Alternating Gradient Synchrotron to accelerate iron ion beams (Experiment 947, BNL-5). These experiments were part of NASA's Space Radiation Health Program (SRHP) heavy ion radiobiology research program at BNL.

A total of 22 proposals were approved to participate in the BNL-4 run, 16 of which were returnees from 1998's BNL-4. Three groups were new participants. From the total number 22 were full proposals and 1 was a piggyback experiment. Fourteen institutions from United States, and 1 from Japan were represented, totaling 64 users. More than 998 biological samples were irradiated at the AGS A-3 beam line, employing 104.5 hours of beam time. In addition, 24 hours were used for physics experiments, and a total of 52.5 hours were necessary for beam characterization, tuning, dosimetry, and calibration.

During BNL-5, AGS provided iron beams with two energies: 1 GeV/nucleon (1.06 GeV/nucleon*, LET: 148 keV/μm), and 0.6 GeV/nucleon (0.561.4 GeV/nucleon*, LET: 177 keV/μm) for biology and physics experiments. The dose/rates used were as low as 50 cGy/min and as high as 9 Gy/min for 1 GeV/nucleon, and from 45 cGy/min up to 10 Gy/min for 0.6 GeV/nucleon iron beams. The spill rate employed was 30 spills/min with a duration of 500 msec/spill. The spill fluence was (particles/spill) 1.4×10^8 (max) and 6.5×10^6 (min) for 0.6 GeV/nucleon, and 1.67×10^8 (max) and 1.67×10^7 (min) for 1 GeV/nucleon. The intensities (particles/cm²/sec on target) used during the run were 5.88×10^5 (max) and 2.65×10^4 (min) for 0.6 GeV/nucleon, and 6.33×10^5 (max) and 6.33×10^4 (min) for 1 GeV/nucleon. A 7.5-cm diameter beam spot was employed for the exposures.

Radiobiological experiments employed cells, tissues, and intact specimens, which required a complex coordination and planning of their respective logistic support. Biological studies used human, mouse, rat, hamster and canine cell lines (25), human-hamster hybrid cell lines, and intact specimens (rodents). The full program was completed in 10 days under the AGS's operation schedule directives and with the allocated beam time dedicated for the NASA radiobiology program.

* Actual beam energy on target

BNL-5 PARTICIPANTS

Exp.	Participants	Affiliation	Title
B-1	J. Miller L. Heilbronn C. Zeitlin R.P. Sigh M. Nyman	Lawrence Berkeley National Laboratory, CA " " " "	Ph.D., Principal Investigator Ph.D., Co-Principal Investigator Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker
B-2	D. Chen * X. Cui T. Hei	Los Alamos National Laboratory, NM " Columbia University, NY	Ph.D., Principal Investigator Ph.D. student-Co-Worker Ph.D., Co-Worker
B-3	H. Wu D. Morrison K. George H. Soehnge V. Willingham T. Kawata Y. Furusawa	NASA, Johnson Space Flight Center, TX " " " " " NIRS, Japan	Ph.D., Principal Investigator Co-Worker Co-Worker Co-Worker Co-Worker Co-Worker Co-Worker
B-9	B. Sutherland P. Bennett J. Sutherland J. Trunk D. Monteleone	Brookhaven National Laboratory, NY " " " "	Ph.D., Principal Investigator MS., Biology Associate. Ph.D., Co-Worker Co-Worker Co-Worker
B-12	T. Hei C. Piao R. Miller M. Suzuki	Columbia University, NY " " "	Ph.D., Principal Investigator Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker
B-15	C. Waldren * T. Hei	Colorado State University, CO Columbia University, NY	Ph.D., Principal Investigator Ph.D., Co-Investigator
B-18	P. Cooper B. Rydberg E. Kwoh	Lawrence Berkeley National Laboratory, CA " "	Ph.D., Principal Investigator Ph.D., Co-Principal Investigator Co-Investigator
B-19 B-20	A. Kronenberg C. Wiese S. Gauny J. Haim H. Bethel	Lawrence Berkeley National Laboratory, CA " " " "	Ph.D., Principal Investigator Post-Doctoral Student Senior Research Associate Ph.D., Co-Worker Grad. Student, Co-Worker
B-23	A. Brooks S. Bao K. Rithidech	Washington State University, WA " SUNY Stony Brook, NY	Ph.D., Principal Investigator Co-Worker Ph.D., Co-Worker
B-25	H. Evans T. Evans	Case Western Reserve University, OH "	Ph.D., Principal Investigator Co-Worker
B-32	J. Dicello S. Howard J. Williams J. Strandberg D. Huso Y. Zhang Mann Simonson Zhou Arbona Nachman	NSBRI, John Hopkins University, MD " " " " " " " " " " "	Ph.D., Principal Investigator MD. Ph.D., Co-Worker Sc.D. Co-Worker Ph.D. Co-Worker DVM, Ph.D., Co-Worker M.D. Co-Worker
B-33	R. Sinden	NSBRI, John Hopkins University, MD	Ph.D., Principal Investigator
B-34	J. Bedford T. Hei	Colorado State University Columbia University, NY	Ph.D., Principal Investigator Ph.D., Co-Principal Investigator

Exp.	Participants	Affiliation	Title
B-35	G. Nelson L. Green D. Murray T. Jones	Loma Linda University “ “ “	Ph.D., Principal Investigator Ph.D., Co-Worker Co-Worker Co-Worker
B-36	G. Illiakis Z. Zeng	Thomas Jefferson University “	Ph.D., Principal Investigator Ph.D., Co-W
B-37	R. Ullrich C. McArthy	University of Texas Medical Branch “	Ph.D., Principal Investigator Co-Worker
B-38	F. Burns J. Xu P. Zohng	New York University Medical Center “ “	Ph.D., Principal Investigator Co-Worker Co-Worker

PARTICIPANTS STATISTICS

PARTICIPANTS	BNL-5
Ph.D., Principal Investigators	17
Ph.D., Co-Principal Investigators	4
Co-Workers	18
Ph.D.	16
MD, Ph.D.	1
DVM, Ph.D.	1
M.D.	1
Sc.D.	1
M.S.	1
Graduate Students	1
Ph.D. Students	1
Post-Doctoral Students	1
Senior Research Associates	2
Total:	64

Participant Institutions

- Brookhaven National Laboratory, NY
- Lawrence Berkeley National Laboratory, CA
- Los Alamos National Laboratory, NM
- NASA, Johnson Space Flight Center, TX
- National Space Biology Research Institute, (J. Hopkins, MD and Texas A&M University, TX)
- Case Western Reserve University, OH
- Columbia University, NY
- Colorado State University, CO
- Loma Linda University Medical Center, CA
- New York University Medical Center, NY
- Thomas Jefferson University, PA
- University of Texas Medical Branch, TX
- Washington State University, WA
- National Institute of Radiological Sciences, Japan

RUN DATES

Run dates	Scheduled		Actual	
	Date	Time	Date	Time
Run start	5/10	0800	5/10	0800
Run end	5/18	1630	5/20	0100
Tuned into cave	5/9	0800	5/9	0800
Beam delivered for Biology				
A- Fe 1 GeV/n	5/11	0000	5/11	0900
End run	5/16	2030	5/16	1930
B- Fe 1 GeV/n	5/17	1900	5/18	1300
End run	5/18	1630	5/20	0100
Fe 0.6 GeV/n	5/16	2200	5/17	1330
End run	5/17	0430	5/17	1630

BEAM TIME DESCRIPTION (hours)

Total Clock Time	(from 5/10 0800 to 5/20 0100)	234
Total Beam-on Time		190
Total Beam-off time		44
Beam Time for Biology		
1 GeV/n	101.5	
0.6 GeV/n	3	
Sub-total		104.5
Beam Time for Physics		
1 GeV/n	12	
0.6 GeV/n	12	
Sub-total		24
AGS Studies		10
Beam time for dosimetry, calibration, tuning, etc.		
1 GeV/n	41.5	
0.6 GeV/n	11	
Sub-total		52.5
Totals		190

BEAM CHARACTERISTICS

	⁵⁶ Fe ²⁶ 600 MeV/n	⁵⁶ Fe ²⁶ 1000 MeV/n
Fluence (particles/cm²/sec)		
Maximum on target	5.88 x 10 ⁵	6.33 x 10 ⁵
Minimum on target	2.65 x 10 ⁴	6.33 x 10 ⁴
Spill rate	30 spills/min	30 spills/min
Spill length	500 msec	500 msec
Particles/spill		
Maximum	1.4 x 10 ⁸	1.67 x 10 ⁸
Minimum	6.5 x 10 ⁶	1.67 x 10 ⁷
Beam spot diameter	7.5 cm	7.5 - 9 cm
Beam cut off length.	<1%	<1%
Actual Energy		
Extracted	599+/-10 MeV/n	1087 MeV/n
On Target	561.4+/-10 MeV/n	1060 MeV/n
Actual LET	177 keV/μm	148 keV/μm
Dose/rate recorded.		
Maximum	10 Gy/min	9.0 Gy/min
Minimum	0.45 Gy/min	0.9 Gy/min
Minimum dose exposure	0.005 Gy	0.001 Gy
No of hours for beam characterization, tuning and dosimetry	11	41.5

BNL-5 EXPERIMENTERS AND RUN STATISTICS

Exp. ID	Principal Investigator	Energy	Beam Time Approved	Beam Time Used	Dose Range (cGy)	Dose/Rate (cGy/min)	Number of Samples
B1	Miller	1 GeV 600 MeV	12 12	12 12	NA	NA	NA
B2	Chen	1 GeV	2	0.5	NA	NA	NA
B3	Wu	1 GeV 600 MeV	4 1.5	4 1.5	50 - 500	100	NA
B9	Sutherland	1 GeV 600 MeV	5 1.5	5 1.5	NA	NA	NA
B12	Hei	1 GeV	4	3	8.4 - 125	100	35
B15	Waldren	1 GeV	4	0.5	50 - 200	100	45
B18	Cooper	1 GeV	20	18	25 - 8000	100 - 700	348
B19-20	Kronenberg	1 GeV	22	22	30 - 8000	<100 - 700	NA
B23	Brooks	1 GeV	1.5	1.5	100 - 200	100	16
B25	Evans	1 GeV	2.5	3	0.5 - 2.5	100	36
B32	Dicello	1 GeV	19	20	5 - 100	100	300
B33	Sinden	1 GeV	2	2	10 - 100	100	75
B34	Bedford	1 GeV	1.5	0.5	84 - 125	100	24
B35	Nelson	1 GeV	3	4	50 - 2500	100 - 700	NA
B36	Illiakis	1 GeV	2	1.5	150 - 300	100	20
B37	Ullrich	1 GeV	2	1.5	2 - 20	50	18
B39	Burns	1 GeV	13	15	600	300	100
Totals			135.2 hr	128 hr	2 to 8000cGy	50 to 700 cGy	998+

BNL-5 PARTICIPANTS AND EXPERIMENTAL SAMPLES

Exp.	Participants	Samples	Institution
B-1	J. Miller (PI)	Solid state detectors	Lawrence Berkeley National, CA
B-2	D. Chen (PI)	Human-hamster hybrid cell line (IRS1-SF and XRCC2)	Los Alamos National Laboratory, NM
B-3	H. Wu	Human Fibroblasts Human Lymphocytes	NASA, Johnson Space Flight Center, TX
B-9	B. Sutherland (PI)	Human skin fibroblast and epithelial cells	Brookhaven National Laboratory, NY
B-12	T. Hei (PI)	AG1521A Cells	Columbia University, NY
B-15	C. Waldren (PI)	Human-hamster hybrid cell line (A _L)	Colorado State University, CO
B-18	P. Cooper (PI)	Human fibroblasts Mouse Embryonic Fibroblast (MEF) Human cell line NBS	Lawrence Berkeley National Laboratory, CA
B-19	A. Kronenberg (PI)	Human lymphoid cells (TK6) WTK-bclX _L	Lawrence Berkeley National Laboratory, CA
B-20	A. Kronenberg (PI)	TK6 cells	Lawrence Berkeley National Laboratory, CA
B-23	A. Brooks (PI)	Rats (Wistar) Rat epithelial cells from lungs, trachea and bone marrow.	Washington State University, WA
B-25	H. Evans (PI)	Human lymphoblast (TK6 and WTK1) Murine Lymphoblast (LY-S1, LY-SR1)	Case Western Reserve University, OH
B-32	J. Dicello	Sprague-Dawley Rats, Rat and Human Mammary Epithelial Cells	National Space Biology Research Institute, J. Hopkins, MD
B-33	R. Sinden	Fibrosarcoma cell lines (F14C-23 and 122-2)	National Space Biology Research Institute, Texas A&M University, TX
B-34	J. Bedford	AG1521A Cells	Colorado State University, CO
B-35	G. Nelson	Worms (C. Elegans) FRTL-5 Cells	Loma Linda University Medical Center, CA
B-36	G. Illiakis	A1-5 cell line	Thomas Jefferson University, PA
B-37	B. Ullrich	BALB/c ByJ mice	University of Texas Medical Branch, TX
B-39	F. Burns	Rats	NYU Medical Center, NY