



BNL-7 RUN

FINAL REPORT

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TABLE OF CONTENTS

Executive Summary	3
BNL-7 Proposals	4
Participants	5
Participants Statistics	7
Participants Institutions	8
Run Dates/Beam Time Description	9
Statistics	10
Beam Characteristics	11
Run Statistics and Incidents	12
Experimenters and Run Statistics	13
Participants, Experimental Samples and Endpoints	14
List of Personnel	16

EXECUTIVE SUMMARY

During the Winter of 2001, a series of radiobiological and physics experiments were performed using the BNL's Alternating Gradient Synchrotron to accelerate iron ion beams (Experiment 957, BNL-7). These experiments were part of the seventh consecutive run sponsored by NASA's Space Radiation Health Program (SRHP) heavy ion radiobiology research program at BNL.

A total of 24 proposals (from 25 proposals submitted) were approved to participate in the BNL-7 run, 7 of which were renewals, four were continuing projects and fourteen, which were new proposals. From the total number 23 were full proposals and 2 were piggyback experiments. Six proposals declined to participate. Nineteen institutions from the United States (10 states), and 5 from foreign countries (Italy, Japan and England) were represented, totaling 81 users. More than 1600 biological samples were irradiated at the AGS A-3 beam line, employing 89.5 hours of beam time. In addition, 37 hours were used for physics experiments, and a total of 21 hours were necessary for beam characterization, tuning, dosimetry, and calibration. A total of 35.5 hours of beam time were lost (19%) due to accelerator or power supply related problems.

During BNL-7, AGS provided iron beams with an energy of: 1 GeV/nucleon (1.046 GeV/nucleon*, LET: 148 keV/ μm), for biology and physics experiments. The dose/rates used were as low as 10 cGy/min and as high as 15 Gy/min. The spill rate employed was 30 spills/min with a duration of 500-600 msec/spill. The spill fluence was (particles/spill) 1×10^8 (max) and 1.5×10^5 (min). The intensities (particles/ cm^2/sec on target) used during the run were 1×10^8 (max) and 400 (min). A 7.5-cm diameter beam spot was employed as a nominal spot for the majority of the exposures. For larger samples (animals), an elliptical spot was used (up to 9 cm).

Tandem-Booster set-up started on Jan. 4 with the transport and circulation of Fe beams at the AGS complex. Beam was tuned into cave on Jan. 6 and 1.08 GeV/u ^{56}Fe beam was available for tuning on Jan. 8. The next several shifts were spent on tuning into the target area, beam diagnostics and establishing several different combinations of beam intensities and spot shapes and sizes for biology running. Biology studies started early on Jan. 9 (biology, NYU Medical Center, F. Burns) and proceeded with several interruptions through early Jan. 11, after which the machine operations was more stable. After all biology experiments were completed, LBNL (C. Zeitlin) ran 37 hours of fragmentation physics studies with 1.2 GeV/u ^{56}Fe . BNL-7 finished at 2300 PM on Jan. 15

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 and hamster cell lines, human-hamster hybrid cell lines, tumor cell lines and intact specimens (rodents and fish). Physics experiments involved the exposure of solid state detectors and spacecraft materials. The full program was completed in 8 days.

*Actual beam energy on target

BNL-7 Projects Reviewed by the BNL's Scientific Advisory Committee in Radiobiology

Project	P.I.	Status	SACR Review	BNL-7 Participation
B-1	Miller	Renewal	Approved	Yes
B-7	Rabin	Renewal	Approved	Yes
B-10	P. Chang	New	Approved	No
B-12	Hei	Continuing	Approved	Yes
B-18	Cooper	New	Approved	Yes
B-19/20	Kronenberg	Renewal	Approved	Yes
B-25	Evans	Renewal	Approved	Yes
B-29	Natarajan*	Renewal	Approved	Yes
B-30	Kale	Continuing	Approved	No
B-32	Dicello	Renewal	Approved	Yes
B-39	Burns	Renewal	Approved	Yes
B-42	Barcellos-Hoff	Continuing	Approved	Yes
B-43	Nelson	Continuing	Approved	Yes
B-44	Durante/Belli	New	Approved	Yes
B-45	Setlow	New	Approved	Yes
B-46	Barbanel	New	Not Approved	No
B-47	Nelson	New	Approved	Yes
B-48	Green	New	Approved	Yes
B-49	Cucinota-Kawata	New	Approved	No
B-50	Cucinota-Wu	New	Approved	No
B-51	Murnane	New	Approved	Yes
B-52	Gerwitz	New	Approved	Yes
B-53	Lupton	New	Approved	Yes
B-54	Kennedy	New	Approved	No
B-55	Vazquez	New	Approved	Yes

*Piggyback experiment with B-47 project (Nelson)

BNL-7 PARTICIPANTS

Exp.	Participants	Affiliation	Title
B-1	C. Zeitlin. J. Miller L. Heilbronn R.P. Sigh W. Holley M. Nyman W. Schimmerling F. Cuccinota M. Cosolino V. Bidoli W. Sanita L. Narici R. Wilkins H. Huff R. Maurer D. Roth D. Stephens J. Kinnison	Lawrence Berkeley National Laboratory, CA " " " " " NASA, HDQ, DC NASA, JSC, TX University of Rome, Thor Vergara, Italy " " " Prairie View A&M University " APL, John Hopkins University, MD " Colorado State University, CO "	Ph.D., Principal Investigator Ph.D., Co-Principal Investigator Ph.D., Co-Worker Ph.D., Co-Worker Ph.D. Student Ph.D. Student
B-7	B. Rabin J. Joseph B. Sukit-Hale J. McEwen S. Szprengiel	University of Maryland, Baltimore County, MD Human Nutrition Research Center on Aging, MA " "	Ph.D., Principal Investigator Ph.D., Co-Principal Investigator Co-Worker Co-Worker Co-Worker
B-12	T. Hei L. Smilenov C. Piao M. Suzuki	Columbia University, NY " " "	Ph.D. Principal Investigator Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker
B-18	P. Cooper* B. Rydberg B. Cooper	Lawrence Berkeley National Laboratory, CA " "	Ph.D., Principal Investigator Ph.D., Co-Principal Investigator Student
B-19 B-20	A. Kronenberg C. Wiese S. Gauny J. Hain	Lawrence Berkeley National Laboratory, CA " " "	Ph.D., Principal Investigator Post-Doctoral Student Senior Research Associate Ph.D., Co-Worker
B-25	H. Evans T. Evans J. Schwartz	Case Western Reserve University, OH " "	Ph.D., Principal Investigator Co-Worker Ph.D., Co-Worker
B-29	M. Natarajan	The University of Texas Health Sci., TX	Ph.D., Principal Investigator
B-32	J. Dicello D. Huso Y. Zhang J. Man D. Simonson R. Arbona A. Chesnut	NSBRI, John Hopkins University, MD " " " " " "	Ph.D., Principal Investigator DVM, Ph.D., Co-Worker MD. Co-Worker DVM Co-Worker MS. Co-Worker MD. Co-Worker MS. Co-Worker
B-39	F. Burns J. Xu	New York University Medical Center, NY "	Ph.D., Principal Investigator Co-Worker

B-42	M. Barcellos-Hoff* R. Henshall S. Pearson	Lawrence Berkeley National Laboratory, CA “ Colorado State University, CO	Ph.D., Principal Investigator Co-Worker Co-Worker
B-43	G. Nelson T. Jones M. Pecaut A. Smith G. Peterson	Loma Linda University, CA “ “ “ “	Ph.D., Principal Investigator BS., Co-Worker BS, Co-Worker BS, Co-Worker BS, Co-Worker
B-44	M. Durante* M. Belli F. Antonelli G. Simone	University “Federico II”, Napoli, Italy National Institute of Health, Rome, Italy “ “	Ph.D., Principal Investigator Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker
B-45	R. Setlow J. Jardine A. Shima	Brookhaven National Laboratory, NY “ University of Tokyo, Japan	Ph.D., Principal Investigator BS, Co-Worker Ph.D., Co-Worker
B-47	G. Nelson A. Smith G. Peterson R. Dutta-Roy D. Murray M. Kadhim	Loma Linda University, CA “ “ “ “ MRC, England	Ph.D., Principal Investigator Ph.D., Co-Worker BS, Co-Worker BS, Co-Worker BS, Co-Worker Ph.D., Co-Worker
B-48	L. Green* G. Nelson D. Murray T. Jones	Loma Linda University, CA “ “ “	Ph.D., Principal Investigator Ph.D., Co-Worker BS, Co-Worker BS, Co-Worker
B-51	J. Murnane* B. Fouladi	University of California, San Francisco, CA “	Ph.D., Principal Investigator Ph.D., Co-Worker
B-52	J. Gerwitz* B. Sutherland P. Bennett J. Sutherland P. Guida J. Trunk D. Monteleone	NSBRI, University of Pennsylvania Brookhaven National Laboratory, NY “ “ “ “ “	Ph.D., Principal Investigator Ph.D., Co-Investigator MS., Biology Associate. Ph.D., Co-Worker Ph.D., Co-Worker Co-Worker Co-Worker
B-53	J. Lupton* L. Braby N. Turner S. Taddeo N. Popovic M. Young Hong C. Henderson	NSBRI, Texas A&M University, TX “ “ “ “ “ “	Ph.D., Principal Investigator Ph.D., Co-Investigator Ph.D., Co-Investigator Co-Worker Co-Worker Co-Worker Co-Worker
B-55	M. Vazquez Gaofeng Fan Luis Estevez Stefanie Otto Kay Conkling Divine Adika	NSBRI, Brookhaven National Laboratory, NY “ “ “ “ “	MD, Ph.D., Principal Invest. MD, Ph.D., Co-Worker BS, Co-Worker BS, Co-Worker. BS, Co-Worker BS, Co-Worker

*Not present during the actual run

BNL-7 PARTICIPANTS STATISTICS

PARTICIPANTS	BNL-7
Ph.D., Principal Investigators	10
M.D., Ph.D., Principal Investigators	1
Ph.D., Co-Principal Investigators	3
Ph.D., Co-Investigator	3
Co-Workers	11
Ph.D.	29
MD, Ph.D.	1
DVM, Ph.D.	1
M.D.	2
B.S.	11
M.S.	2
DVM	1
Post-Doctoral Students	1
Ph.D., Student	2
MS Biology Associate	1
Senior Research Associates	1
Student	1
Total:	81

BNL-7 PARTICIPANT INSTITUTIONS

NASA related centers/institutes (4)

- **NASA, Headquarters, DC**
- **NASA, Johnson Space Center, TX**
- **NSCORT, LBNL-CSU**
- **National Space Biomedical Research Institute, TX**

National Laboratories/Institutes (3)

- **Brookhaven National Laboratory, NY**
- **Lawrence Berkeley National Laboratory, CA**
- **Human Nutrition Research Center on Aging, MA**

Universities (12)

- **Prairie View A&M University**
- **Colorado State University, CO**
- **APL, John Hopkins University, MD**
- **University of Maryland, Baltimore County, MD**
- **Columbia University, NY**
- **Case Western Reserve University, OH**
- **The University of Texas Health Sciences., TX**
- **New York University Medical Center, NY**
- **Loma Linda University, CA**
- **Texas A&M University, TX**
- **University of California, San Francisco, CA**
- **University of Pennsylvania, PA**

Foreign Institutions (5)

- **University of Rome, Thor Vergara, Italy**
- **University “Federico II”, Napoli, Italy**
- **National Institute of Health, Rome, Italy**
- **University of Tokyo, Japan**
- **MRC, England**

BNL-7 RUN DATES

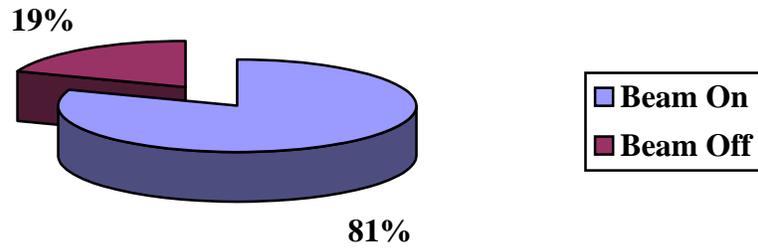
Run dates	Scheduled		Actual	
	Date	Time	Date	Time
Run start	01/08	0800	01/08	0800
Run end	01/14	1400	01/15	2300
Tuned into cave	01/9	0100	01/9	0100
Beam delivered for Biology				
Fe 1 GeV/n	01/09	0100	01/09	0100
End run	01/13	0600	01/14	1000

BEAM TIME DESCRIPTION (hours)

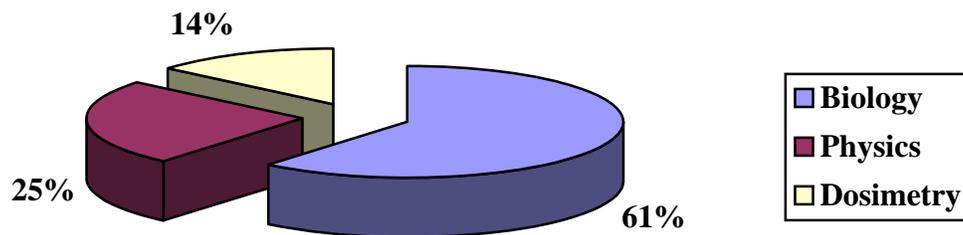
Total Clock Time	(from 01/08 0800 to 01/15 2300)	183
Total Beam-on Time		147.5 (81%)
Total Beam-off time		35.5 (19%)
	Total:	183.0 (100%)
Beam Time for Biology	89.5 (61%)	
Beam Time for Physics	37 (25%)	
Beam time for dosimetry, calibration, tuning, etc.	21 (14%)	
Totals	165	

DESCRIPTIVE STATISTICS

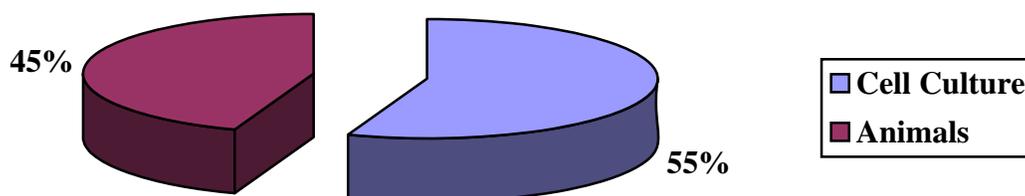
- **AGS Fe 1 GeV/n Beam Availability**



- **Distribution of Beam Time Usage:**



- **Distribution of Beam Time for Biology:**



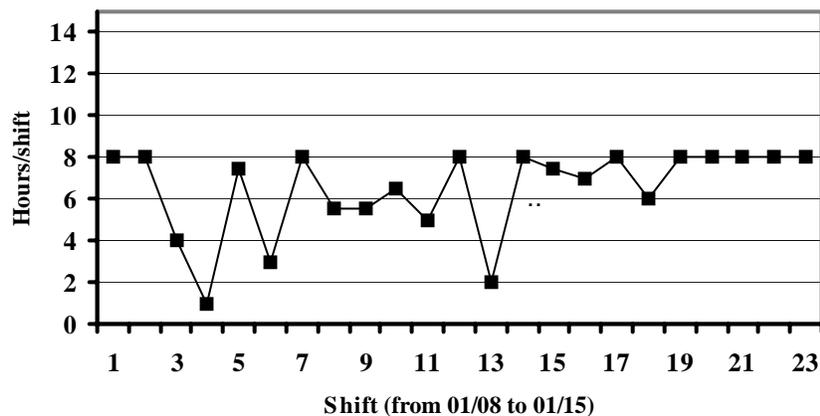
IRON BEAM CHARACTERISTICS

	$^{56}\text{Fe}^{26}$
	1000 MeV/n
Fluence (particles/cm²/sec)	
Maximum on target	1 x 10⁸
Minimum on target	400
Spill rate (spills/min)	18
Spill length (msec)	500-600
Particles/spill	
Maximum	1 x 10⁸
Minimum	1.5 x 10⁵
Beam spot diameter (cm)	5* - 7.5 - 9
Beam cut off length.	<1%
Actual Energy (MeV/n)	
Extracted	1078
On Target	1046
Actual LET on Target (keV/μm)	148
Dose/rate recorded (cGy/min)	
Maximum	1000
Minimum	30
Minimum dose exposure (cGy)	1
No of hours for beam characterization, tuning and dosimetry	21

BNL-7 RUN STATISTICS AND INCIDENTS

Date	Shift	Beam On	Beam Off	Remarks
01/08/01	2	8	0	1 GeV Iron run start, beam tuned into the cave
	3	8	0	Beam tuning for biology.
01/09/01	1	4	4	Biology run start. Power supply trip off.
	2	1	7	Power supply off. Magnet problems.
	3	7.5	0.5	RF problems
01/10/01	1	3	5	Controller for the Booster RF failed
	2	8	0	No incidents
	3	5.5	2.5	RF problems
01/11/01	1	5.5	2.5	RF problems
	2	6.5	1.5	TTB beamstop failure
	3	5	3	Magnets problems
01/12/01	1	8	0	No incidents.
	2	2	6	TTB beamstop failure
	3	8	0	No incidents.
01/13/01	1	7.5	0.5	Beam drift, magnets problems (AQ7&8)
	2	7	1	Beam drift, magnets problems (AD4-9)
	3	8	0	No incidents.
01/14/01	1	6	2	Magnets problems.
	2	8	0	Biology run end. Physics run starts.
	3	8	0	No incidents.
01/15/01	1	8	0	No incidents.
	2	8	0	No incidents.
	3	8	0	No incidents. BNL-7 end.

Beam availability



BNL-7 EXPERIMENTERS AND RUN STATISTICS

Exp. ID	Principal Investigator	Ion & Energy	Beam Time Approved	Beam Time Used	Dose Range (cGy)	Dose/Rate (cGy/min)	Number of Samples
B-1	Zeitlin	Fe, 1 GeV/n	32	37	NA	NA	NA
B-7	Rabin	Fe, 1 GeV/n	9.5	10	100-150	50-150	100
B-12	Hei	Fe, 1 GeV/n	4	2	20-400	100	75
B-18	Cooper	Fe, 1 GeV/n	6	6	60-600	200	50
B-19-20	Kronenberg	Fe, 1 GeV/n	12	10	31 - 189	50-100	NA
B-25	Evans	Fe, 1 GeV/n	6	3	10-400	20-100	32
B-29	Natarajan	Fe, 1 GeV/n	0	1	NA	NA	NA
B-32	Dicello	Fe, 1 GeV/n	10	10	1 - 100	1-100	200
B-39	Burns	Fe, 1 GeV/n	9	14	300	150	72
B-42	Barcellos-Hoff	Fe, 1 GeV/n	5	4	50-200	100	50
B-43	Nelson	Fe, 1 GeV/n	2.5	4.5	10 - 200	100 - 200	120
B-44	Durante	Fe, 1 GeV/n	6	5	1000-40000	1500	200
B-45	Setlow	Fe, 1 GeV/n	2	2	30-100	50-100	200
B-47	Nelson	Fe, 1 GeV/n	4	4.5	50-300	50-200	255
B-48	Green	Fe, 1 GeV/n	0.7	1	10-300	50-200	30
B-51	Murnane	Fe, 1 GeV/n	3	2	400	200	50
B-52	Gerwitz	Fe, 1 GeV/n	2	2.5	NA	NA	NA
B-53	Lupton	Fe, 1 GeV/n	1.5	2	100	100	20
B-55	Vazquez	Fe, 1 GeV/n	6	6	10-200	30-150	200
Totals			122.7 hr	126.5 hr	10-40000	5 to 200	1654+

BNL-7 PARTICIPANTS, EXPERIMENTAL SAMPLES AND ENDPOINTS

Exp.	Participants	Samples	Endpoints
B-1	Heavy Ion Fragmentation and Transport in Matter C. Zeitlin (PI)	Solid state detectors	Heavy ion fragmentation CR39 calibration
B-7	Effects of Exposure to Heavy Ions. B. Rabin (PI)	Sprague-Dawley Rats	Neurological and neurochemical changes
B-12	Cytogenetic and Neoplastic Transforming Effects of Heavy Ions in Mammalian Cells. T. Hei (PI)	Human bronquial epithelial cells (BEP2D) and breast cells (MCF-10F)	Neoplastic transformation, Differential gene expression, mutation spectra by PCR
B-18	DNA Repair and Early Dev. of Chromosomal Changes. Cytog. Studies. P. Cooper (PI)	HeLa cells, human fibroblast, XP-G cell line	Frequency of non-rejoined/misrejoined PCC
B-19 B-20	Mutagenesis and Genomic Instability in Human Lymphoid cells A. Kronenberg (PI)	Human lymphoid cells (TK6) and WTK-bclX _L	Apoptosis induction, mutat collection, cell killing and mutation, DSB rejoining/fidelity
B-25	Induction of Genomic Instability in Human Lymphoblast H. Evans (PI)	LY-S1 and LY-SR1 murine lymphoblast, human colon cancer cells	Protective effects of WR1065 against cytotoxicity and mutagenic effect. Detection by GFP
B-29	NF-KB Mediated Radio-Responsive Gene Transcription after Heavy Ion Radiation Exposure. M. Natarajan (PI)	Human macrophage cells (Mono Mac 6)	Gene expression
B-32	Tumor Formation in Rat Mammary Glands J. Dicello (PI)	Sprague-Dawley Rats, Rat and lymphocytes, Min Mouse	Tumor induction and Tamoxifen protective effects and chromosomal aberrations
B-39	Tumor Induction by High-LET Radiation. F. Burns (PI)	Sprague-Dawley Rats	Skin tumor induction and modulation by dietary retinyl acetate.
B-42	Particle Irradiation of Human Mammary Epithelial Cells M. Barcellos-Hoff (PI)	Human mammary epithelial cells (HMT 3522)	Microenvironment changes, TGF- β and bFGF levels, immunocitochem., apoptosis and neoplastic potential
B-43	Preliminary Assessment of Immune System and behavioral Responses to Accelerated Iron Ion Exposure in the C57B1/6 Mouse. G. Nelson (PI)	Mouse (C57B1/6)	Neurological and immunological alterations
B-44	Influence of the Shielding on the Space rad. Biological Effectiveness. M. Durante (PI)	AG1522 human diploid foreskin fibroblasts	DNA damage and repair. Shielding effects.
B-45	Germ Cell Mutagenesis in Medaka Fish Following Exposure to HZE particle radiation R. Setlow (PI)	Male Medaka fish	Mutation induction
B-47	Genomic Instability in Mouse Hematopoietic Cells in Resp. to Accelerated Iron Ion Exposure. G. Nelson (PI)	C57B1/6 and CBA/Ca mice	Transmissible delayed expression chrom damage. Genomic instability, apoptosis and oxidative stress.

B-48	Radiobiology of thyroid follicular cells. L. Green (PI)	Thyroid cells	Gene expression alterations
B-51	Particle-Ind. Telomere Loss in Human cells. J. Murnane (PI)	SC308H cells	Survival, mutation frequency, chromosomal changes and telomere status.
B-52	Effect of Deep Space Radiation on Human Hematopoietic Stem Cells. A. Gerwitz (PI)	TF-1 cells	DNA damage (DSB and clustered damages)
B-53	Nutritional Countermeasures to Radiation Exposure. J. Lupton (PI)	Sprague-Dawley rats	Gene expression, tumor incidence.
B-55	Risk Assessment and Chemoprevention of HZE-Induced CNS Damage M. Vazquez (PI)	NT2 human neural stem cells	Survival, apoptosis and gene expression.

List of personnel that participated in the planning, organization and execution of BNL-7 run

BNL Management:

- Laboratory Director: **John Marburger**
- Deputy Director for Science & Technology: **Peter Paul**
- Associate Director for High Energy and Nuclear Physics: **Tom Kirk**
- Associate Laboratory Director for Life Sciences: **Nora Volkow**

NASA Management:

- Headquarters: **Walter Schimmerling**
- JSC: **Frank Cucinotta**

Scientific Advisory Committee:

- **Betsy Sutherland** (Chair), BNL
- **Louis Pena**, BNL
- **Richard Setlow**, BNL
- **Joel Bedford**, CSU
- **Les Braby**, PNL
- **Charles Geard**, Columbia University

Collider Accelerator Department-AGS

- Chairman: **Derek Lowenstein**
- Deputy Chairman: **W.T. Weng**
- Associate Chair of Operations: **A.J. McNerney**
- Experimental Planning and Support Head: **Philip Pile**
- Associate Chair for ES&H/Q.A: **E. Lessard**
- ES&H/Q.A : **Peter Cirnigliaro**,
- Accelerator Division Head: **Thomas Roser**
- Chief Electrical Engineer: **J. Sandberg**
- Chief Mechanical Engineer: **J. Tuozzolo**
- Accelerator Physicist lead by: **Leif Aherns**
- Tandem Group leader: **Peter Thieberger**
- Physics Support: **Yusef Makadisi**
- CAD Components and instrumentation support: **David Gassner**
- AGS Radiation Safety Committee: **Ken Reece**
- C-A Dept Training Manager: **John Maraviglia**
- AGS Control Section lead by: **Don Barton**
- Liaison Engineering Group lead by: **Al Pendzick, David Williams**
- Liaison physicist: **Don Lazarus**

- RHIC&AGS Users Center: **Susan White-DePace, Angela Melocoton**
- Mechanical Service Technicians led by: **Fred Kobasiuk**
- Survey Group led by: **Frank Karl**
- Beam Service Technicians led by: **Paul Valli**
- Electronic Service Technicians led by: **Bill Anderson**
- AGS Instrumentation Group led by: **Pete Stillman**
- AGS Main Control Room and Operations led by: **Pete Ingrassia**
- Health Physics Group led by: **Chuck Schaefer**
- AGS Electricians led by **Bill Softye**
- AGS Riggers led by: **Nick Cipolla**
- Carpenter and Welder Support Service and Technical Support led by: **Roger Hubbard**

Medical Department:

- Dept. Chair: **L. Chang**
- Medical Liaison: **Marcelo E. Vazquez**
- Building manager: **W. Gunther**
- Administration: **B. Coughlin-Byrne, and Donna Russo**
- Animal Care Facilities: **Maryann Kershaw, Kerry Bonti, Chris Risland.**
- Tissue Culture Facility manager: **Michael Makar**
- Technical support: **Divine Adika, Katherine Conkling, Bae Pyatt**
- Training Coordinator: **Ann Emrick**
- **RCD**
 - **Kay Conkling**
 - **Dennis Ryan**
 - **Deana Buckallew**
 - **Jim Williams**
 - **Bob Colichio**

Safeguards & Security

- Sam Velazquez,
- Ted Heuer

Plant Engineering:

- BLAF Custodian, **P. Abrams**
- Plumbers: **B. McCafferty**
- Painters/Carpenters: **B. Laakmann**
- Electricians: **T. Baldwin**

Biology Department:

- Chairman: **Carl Anderson**
- **Betsy Sutherland**

- Administration: **Bonnie McGahern**
- Cesium Source Manager: **Richard Satkoulis**

Safety & Environmental Protection Division:

- Manager: **William Fortunato**
- **Dean Atchison**

Lawrence Berkeley National Laboratory:

- **Jack Miller**
- **Lawrence Heilbronn**
- **M. Nyman**
- **R. P. Singh**
- **W. Holley**