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NSRL-6 RUN

FINAL REPORT

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BNL/NASA webpage:
<http://www.bnl.gov/medical/NASA/NASA-home%20frame.htm>

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EXECUTIVE SUMMARY

During the summer of 2005, a series of radiobiological and physics experiments were performed using the NASA Space Radiation Laboratory to accelerate heavy ion beams (NSRL-6). These experiments were part of the sixth NSRL scientific run sponsored by NASA's Space Radiation Health Program (SRHP) heavy ion radiobiology research program at BNL.

A total of 33 proposals were approved by the BNL' SACR to participate in the NSRL-6 run. Thirty three institutions from the United States and 3 from foreign countries (UK and Italy) were represented, totaling 108 users. More than 2000 biological samples were exposed at the NSRL beam line, employing 294 hours of beam time (17.5 hours for in vivo studies, 96 hours for in vitro studies and 69 hours for physics experiments) delivered in a six-weeks period. In addition, 24 hours were used for beam development and, 63 hours for set-up and dosimetry. A total of 23.5 hours of beam time were lost due to accelerator related problems.

During NSRL-6, Booster provided iron (0.308 and 0.969 GeV/nucleon, LET: 236 and 151.1 keV/ μ m), protons (1 GeV/n, LET: 0.222 keV/ μ m), titanium (1 GeV/n, LET: 108 keV/ μ m) and silicon (0.276 and 0.974 GeV/nucleon, LET: 72 and 44 keV/ μ m) ion beams for biology and physics experiments. The dose/rates used were as low as 60 cGy/min and as high as 600 cGy/min. The spill rate employed was 20 with duration of 300 msec/spill. The spill fluence was (particles/spill) 1.6×10^9 (max) and 1×10^5 (min). Square beam spots as big as 20 x 20 cm and small as 1 x 1 cm was employed for biology and physics experiments.

Tandem-Booster set-up started on June 6 with the transport and circulation of p beams at the NSRL complex. Beam was tuned into cave on June 7. 1000 MeV/n p beams were available for tuning on June 7. NSRL-6 officially ended at 0530 am, July 8, 2005 after several hours of biology and physics experiments using Si 600 MeV/n ions.

One of the NSRL-6 highlights, was the second NASA sponsored Space Radiation Summer School on June 1, 2004. The school made use of the NSRL facilities to train 15 students selected by NASA, in the basic concepts of high-LET radiobiology and how to plan and execute an experiment using NSRL. The students and faculty employed 12.3 hours of beam time to expose cell, animals and detectors to titanium ions.

NSRL-6 Projects Reviewed by the BNL's Scientific Advisory Committee in Radiobiology (SACR):

| | Proposal | PI | Sponsor | NSRL-6 Participation |
|-----------|-----------------|---------------------------|------------------|-----------------------------|
| 1 | B3 | Cucinotta | NASA | Yes |
| 2 | B7 | Rabin | NASA | Yes |
| 3 | B44 | Durante | ASI | Yes |
| 4 | B52 | Gewirtz | NSBRI | Yes |
| 5 | B64 | Vazquez | NSBRI | Yes |
| 6 | B65 | Vazquez | NSBRI | Yes |
| 7 | B67 | Blakely | NASA | No |
| 8 | B73 | Sutherland | NASA/DOE | Yes |
| 9 | N80 | Gonda | NASA | Yes |
| 10 | N88 | Sutherland | NASA | Yes |
| 11 | N89 | Held | NASA | Yes |
| 12 | N90 | Bailey | NASA | Yes |
| 13 | N91 | Rydberg | NASA | Yes |
| 14 | N96 | Nelson | NASA | No |
| 15 | N97 | Kronenberg | NASA | Yes |
| 16 | N99 | Zhao | NASA | Yes |
| 17 | N103 | Barcellos-Hoff | NASA | Yes |
| 18 | N104 | Weil/Ullrich | NASA | Yes |
| 19 | N105 | Chatterjee/Bedford | NASA | Yes |
| 20 | N115 | Bacher | NASA | Yes |
| 21 | N116 | Benton | NASA | Yes |
| 22 | N120 | Redpath | DOE/NASA | Yes |
| 23 | N128 | Vazquez | NASA | Yes |
| 24 | N129 | Limoli | NASA | No |
| 25 | N132 | Amundson | NASA | Yes |
| 26 | N134 | Chen | NASA | Yes |
| 27 | N136 | Britt | NASA | Yes |
| 28 | N137 | Wilkins | NASA/JSC | Yes |
| 29 | N140 | Saganti | NASA/CARR | Yes |
| 30 | N142 | Burns | NASA | No |
| 31 | N145 | O'Banion | NASA | Yes |
| 32 | N146 | Wu | NASA | Yes |
| 33 | N151 | Posner | NASA | Yes |

NSRL-6 PARTICIPANTS

| Exp. | Participants | Affiliation | Title |
|-------------|--|--|--|
| B-3 | F. Cucinotta* H. Wu K. George L. Ren M. Hada | NASA, Johnson Space Center “ “ “ “ | Ph.D, Principal Investigator Ph.D., Co-Worker M.S., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker |
| B-7 | B. Rabin J. Joseph* B. Shukitt-Hale A. Carey K. Carrahill | UMBC, Baltimore, MD HNRCA, USDA-ARS, Boston, MA “ “ “ | Ph.D, Principal Investigator Ph.D., Co-Worker Ph.D., Co-Worker B.S., Co-Worker B.S., Co-Worker |
| B-44 | M. Durante G. Grossi V. Togo | University Federico II, Italy “ “ | Ph.D, Principal Investigator Ph.D, Co-Worker Ph.D, Co-Worker |
| B-52 | A. Gewirtz* B. Sutherland P. Bennett M. Naidu D. Roy M. Hada G. Zhou J. Sutherland S. Tafrov D. Monteleone J. Trunk N. Cuomo | University of Pennsylvania BNL, Upton, NY “ “ “ “ ” “ “ “ “ “ “ “ | Ph.D, Principal Investigator Ph.D., Co-Principal Investigator M.S., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker B.S., Co-Worker B.S., Co-Worker B.S., Co-Worker |
| B-64 | M. Vazquez A. Billups B. Pyatt L. Thompson | BNL, Upton, N.Y. “ “ “ | MD, PhD., Principal Investigator B.A., Co-Worker M.S., Co-Worker B.S., Co-Worker |
| B-65 | M. Vazquez P. Guida L. Thompson A. Kim | BNL, Upton, N.Y. “ “ “ | MD, PhD., Principal Investigator Ph.D., Co-Worker B.S., Co-Worker B.S., Co-Worker |
| B-73 | B. Sutherland P. Bennett M. Naidu D. Roy M. Hada G. Zhou J. Sutherland S. Tafrov D. Monteleone J. Trunk N. Cuomo | BNL, Biology Dept., Upton, NY “ “ “ “ ” “ “ “ “ “ “ “ | Ph.D, Principal Investigator M.S., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker B.S., Co-Worker B.S., Co-Worker B.S., Co-Worker |
| N-80 | S. Gonda E. Behraves K. Emami H. Wu | NASA, Johnson Space Center, TX “ “ “ | Ph.D, Principal Investigator Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker |

| Exp. | Participants | Affiliation | Title |
|-------------|---|--|--|
| N-88 | B. Sutherland P. Bennett M. Naidu D. Roy M. Hada G. Zhou J. Sutherland S. Tafrov D. Monteleone J. Trunk N. Cuomo | BNL, Biology Dept., Upton, NY “ “ “ “ ” “ “ “ “ “ “ | Ph.D, Principal Investigator M.S., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker B.S., Co-Worker B.S., Co-Worker B.S., Co-Worker |
| N-89 | K. Held H. Yang V. Anzenberg M. Mohiuddin | Massachusetts Gen. Hosp./Harvard M. School Massachusetts General Hospital Massachusetts General Hospital/MIT | Ph.D., Principal Investigator Ph.D., Co-Worker B.S., Co-Worker B.S., Co-Worker |
| N-90 | S. Bailey B. Sutherland | Colorado State University, Co BNL, Biology Dept., Upton, NY | Ph.D., Principal Investigator Ph.D., Co-Worker |
| N-91 | B. Rydberg T. Groesser B. Cooper | LBNL, Berkeley, CA “ “ | Ph.D, Principal Investigator M.S., Co-Worker Ph.D., Co-Worker |
| N-97 | A. Kronenberg S. Gauny L. Connolly M. Turker H. Sudo E. Kwoh | LBNL, Berkeley, CA “ Oregon Health & Science University “ LBNL, Berkeley, CA “ | Sc.D., Principal Investigator M.S., Co-Worker B.S., Co-Principal Investigator Ph.D., Co-Worker Ph.D., Co-Worker B.S., Co-Worker |
| N-99 | Y. Zhao C. Piao | Columbia University, NY “ | Ph.D, Principal Investigator Ph.D., Co-Worker |
| N-103 | M. Barcellos-Hoff* B. Rydberg A. Kumari S. Costes | LBNL, Berkeley, CA “ “ “ | Ph.D, Principal Investigator Ph.D., Co-Worker Ph.D., Co-Worker Ph.D, Co-Worker |
| N-104 | M. Weil R. Ullrich P. Genik A. Ray M. Callan | Colorado State University “ “ “ “ | Ph.D, Principal Investigator Ph.D., Co-Principal Investigator M.S., Co-Worker M.S., Co-Worker B.S., Co-Worker |
| N-105 | A. Chatterjee* J. Bedford* P. Wilson | LBNL, Berkeley, CA Colorado State University “ | Ph.D, Principal Investigator Ph.D, Co-Principal investigator B.S., B.A., Co-Worker |
| N-115 | J. Bacher R. Halberg L. Motta | Promega University “ “ | Ph.D, Principal Investigator Ph.D, Co-Worker Ph.D, Co-Worker |
| N116 | E. Benton B. Gersey J. Sodolak J. Wedeking | ERIL Res.Inc., CA Praire View A&M University, TX “ “ | Ph.D, Principal Investigator Ph.D., Co-Worker Student “ |
| N120 | J.L. Redpath E. Elmore | University of California Irvine “ | Ph.D., Principal Investigator Ph.D., Co-Worker |

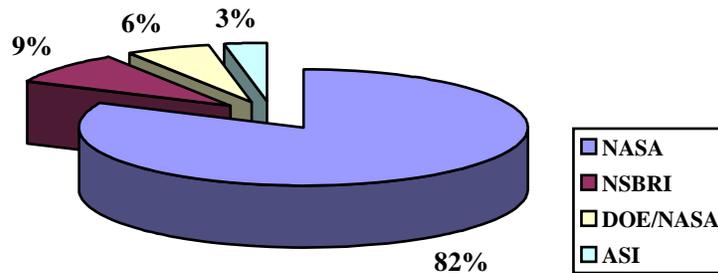
| Exp. | Participants | Affiliation | Title |
|-------------|---|--|---|
| N128 | M. Vazquez P. Guida A. Billups B. Pyatt L. Thompson A. Kim G. Nelson A. Maslowski A. Patterson A. Bertucci B. Mascialino D. Trani D. Thompson G. Sawakuchi H. Li H. Sudo J. Harper J. Meador M. Sanchez R. Mukhopadhyay S. Hurley S. Bhattacharya | BNL, Upton, N.Y. “ “ “ “ Loma Linda University Texas A&M University National Institutes of Health University “Federico II” Naples, Italy University “Federico II” Naples, Italy Temple University Leicester University, Space Research Centre Oklahoma State University Harvard School of Public Health Lawrence Berkeley National Laboratory RAGSU, DNA Damage Group USRA C/O NASA/JSC Loma Linda University Lawrence Berkeley National Laboratory University of Rochester Medical Center NASA Ames Research Center | MD, PhD., Principal Investigator Ph.D., Co-Worker B.A., Co-Worker M.S., Co-Worker B.S., Co-Worker B.S., Co-Worker Ph.D., Co-Worker B.S., Co-Worker B.S., Co-Worker Ph.D., Co-Worker B.S., Co-Worker B.S., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker B.S., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker |
| N-132 | S. Amundson J. Ahn | Columbia University “ | Ph.D., Principal Investigator Staff Associate, Co-Worker |
| N-134 | D. Chen* M. Story S. Burma L. Ding N. Uematsu | University of Texas, Southwestern Medical Center at Dallas “ LBNL, Berkeley, CA “ | Ph.D., Principal Investigator Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker Ph.D., Co-Worker |
| N-136 | A. Britt | University of CA, Davis | Ph.D., Principal Investigator |
| N-137 | R. Wilkins B. Gersey | Prairie View A&M University “ | Ph.D., Principal Investigator Ph.D., Co-Principal Investigator |
| N-140 | P. Saganti B. Gersey R. Wilkins C. Zeitlin | NASA – CARR, Prairie View A&M Univ. “ “ LBNL, Berkeley, CA | Ph.D., Principal Investigator Ph.D., Co-Principal Investigator Ph.D., Co-Principal Investigator Ph.D., Co-Principal Investigator |
| N-145 | K. O’Banion J. Williams S. Hurley L. Trojanczyk | University of Rochester Medical Center “ “ “ | Ph.D., Principal Investigator Ph.D., Co-Worker “ “ |
| N-146 | H. Wu N. Desai J. Meador M. Hada | NASA, Johnson Space Center Wyle Laboratories/JSC USRA/JSC USRA/JSC | Ph.D., Principal Investigator Ph.D., Co-Worker “ “ |
| N-151 | A. Posner D. Hassler M. Maple | Southwest Research Institute “ “ | Ph.D., Principal Investigator Ph.D., Co-Worker Ph.D., Co-Worker |

*Not Present During Actual Run

NSRL-6 PARTICIPANTS STATISTICS

| PARTICIPANTS | NSRL-6 |
|--------------------------------------|------------|
| Ph.D., Principal Investigators | 22 |
| M.D., Ph.D., Principal Investigators | 1 |
| Ph.D., Co-Principal Investigators | 3 |
| B.S., Co-Principal Investigator | 1 |
| Co-Workers | |
| Ph.D. | 46 |
| M.D., Ph.D. | 0 |
| M.D. | 2 |
| M.S. | 7 |
| B.S. | 21 |
| B.A. | 1 |
| B.S./B.A. | 1 |
| Staff Associates | 1 |
| Student | 2 |
| Total: | 108 |

RESEARCH PROJECT SPONSORS:



PARTICIPANT INSTITUTIONS

NASA related centers/institutes (5)

- NASA, Johnson Space Center
- NASA Ames Research Center
- NASA – CARR, Prairie View A&M Univ.
- USRA/JSC
- NSBRI

National Laboratories/Institutes (3)

- Brookhaven National Laboratory, NY
- Lawrence Berkeley National Laboratory, CA
- National Institutes of Health

Universities (21)

- **UMBC, Baltimore, MD**
- **University of Pennsylvania**
- **Colorado State University, Co**
- **Oregon Health & Science University**
- **Columbia University, NY**
- **Massachusetts Gen. Hosp./Harvard M. School**
- **Massachusetts General Hospital/MIT**
- **Loma Linda University**
- **Praire View A&M University, TX**
- **University of California Irvine**
- **Texas A&M University**
- **Temple University**
- **Oklahoma State University**
- **Harvard School of Public Health**
- **University of Rochester Medical Center**
- **University of California San Francisco**
- **University of Texas, Southwestern Medical Center at Dallas**
- **University of CA, Davis**
- **New York University School of Med**
- **University of Rochester Medical Center**
- **Southwest Research Institute**

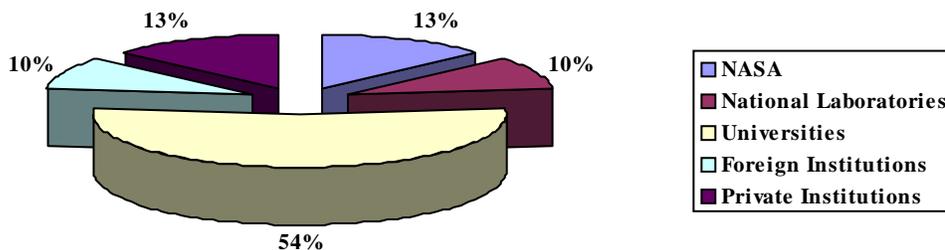
Private Institutions (4)

- **Massachusetts General Hospital, MA**
- **ERIL Research Inc., CA**
- **Promega Corporation, WI**
- **Southwest Research Institute**

Foreign Institutions (3)

- **University Federico II, Naples, Italy**
- **Leicester University, Space Research Centre, England**
- **RAGSU, DNA Damage Group, UK**

INSTITUTIONS STATISTICS:

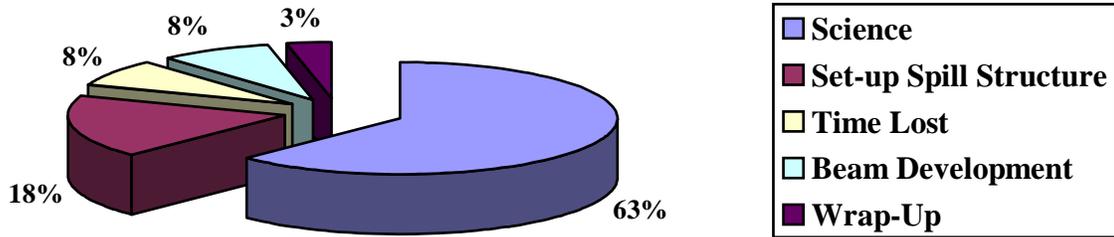


RUN TIME DESCRIPTION (hours)

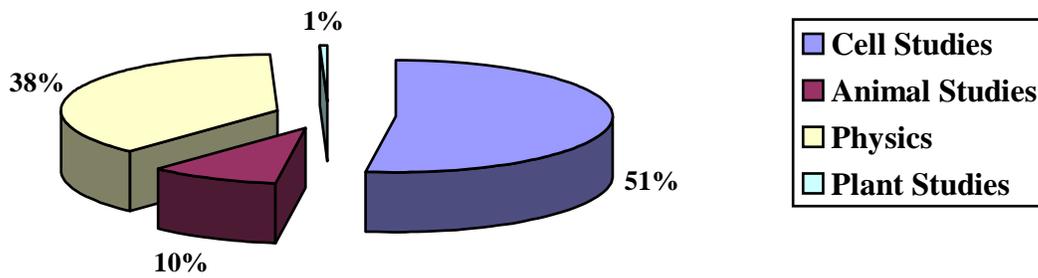
| NSRL-6 | ION SPECIES AND ENERGIES (MeV/n) | | | | | | Totals |
|----------------------------------|----------------------------------|-------------|-------------|------------|-----------|-------------|------------|
| | Ti 1000 | H 1000 | Fe 300 | Fe 1000 | Si 300 | Si 1000 | |
| Set-Up-Spill S. | 12.5 | 6.5 | 10 | 16.5 | 6 | 1.5 | 53 |
| Wrap-Up | 2 | 1 | 1 | 4.5 | 1 | 0.5 | 10 |
| Non-Science Sub-Total: 63 | | | | | | | |
| B. Develop. | 3 | 0 | 0 | 18.5 | 0 | 3 | 24.5 |
| Time lost | 2.5 | 0 | 3 | 16 | 1.5 | 0 | 23 |
| Biology | | | | | | | |
| • In Vitro | 19.5 | 13 | 11 | 40.5 | 7 | 5 | 96 |
| • In Vivo | 8 | 0 | 0 | 9.5 | 0 | 0 | 17.5 |
| • Others | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| Physics | 10 | 0 | 22.5 | 6.5 | 17.5 | 12.5 | 69 |
| Science Sub-Total: 183.5 | | | | | | | |
| Totals | 57.5 | 20.5 | 47.5 | 113 | 33 | 22.5 | 294 |

DESCRIPTIVE STATISTICS

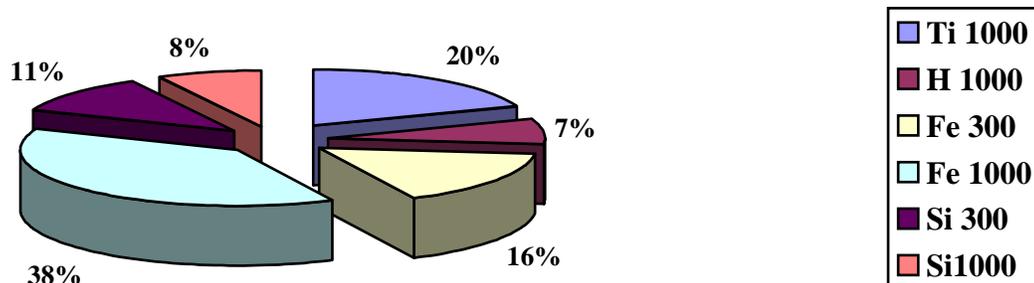
Total NSRL-6 Stats:



Science Studies Stats:



NSRL-5 Ion Species and Energy (MeV/n) Distribution



RUN DATES

| | Scheduled | | Actual | |
|---------------------|--------------|-------------|--------------|-------------|
| | Date | Time | Date | Time |
| H 1000 MeV/n | | | | |
| R 1 Start | 06/07 | 0700 | 06/07 | 0700 |
| End | 06/08 | 1600 | 06/08 | 1830 |

| | Date | Time | Date | Time |
|----------------------|--------------|-------------|--------------|-------------|
| Ti 1000 MeV/n | | | | |
| R 1 Start | 06/09 | 0700 | 06/09 | 0700 |
| End | 06/15 | 1500 | 06/15 | 1500 |

| | Date | Time | Date | Time |
|---------------------|--------------|-------------|--------------|-------------|
| Fe 300 MeV/n | | | | |
| R 1 Start | 06/15 | 1500 | 06/15 | 1500 |
| End | 06/16 | 1700 | 06/16 | 1430 |
| R 2 Start | 06/30 | 0000 | 06/30 | 0600 |
| End | 07/01 | 2000 | 07/01 | 1830 |

| | Date | Time | Date | Time |
|----------------------|--------------|-------------|--------------|-------------|
| Fe 1000 MeV/n | | | | |
| R 1 Start | 06/17 | 0700 | 06/16 | 1430 |
| End | 06/29 | 0000 | 06/29 | 1800 |

| | Date | Time | Date | Time |
|---------------------|--------------|-------------|--------------|-------------|
| Si 300 MeV/n | | | | |
| R 1 Start | 07/05 | 0700 | 07/05 | 0700 |
| End | 07/06 | 2300 | 07/06 | 1730 |

| | Date | Time | Date | Time |
|----------------------|--------------|-------------|--------------|-------------|
| Si 1000 MeV/n | | | | |
| R 1 Start | 07/07 | 0700 | 07/07 | 0700 |
| End | 07/08 | 0800 | 07/08 | 0530 |

NSRL-6 BEAM CHARACTERISTICS

| Ion | Fe | | H | Ti | Si | |
|---|-------|-------|--------|-------|-------|-------|
| Planned Energy (MeV/n) | 300 | 1000 | 1000 | 1000 | 300 | 1000 |
| Fluence (particles/cm ² /sec) | | | | | | |
| Maximum on target | 3.0e6 | 3.0e6 | 2.1e8 | 2.6e6 | 4.5e6 | 4.5e6 |
| Minimum on target | 200 | 200 | 200 | 200 | 200 | 200 |
| Spill Period (sec) | 3 | 3 | 3 | 3 | 3 | 3 |
| Spill rate (spills/min) | 20 | 20 | 20 | 20 | 20 | 20 |
| Spill length (msec) | 300 | 300 | 300 | 300 | 300 | 300 |
| Particles/spill | 1.0e9 | 1.0e9 | 9.0e10 | 6.0e8 | 1.6e9 | 1.6e9 |
| Maximum | 1.0e5 | 1.0e5 | 1.0e5 | 1.0e5 | 1.0e5 | 1.0e5 |
| Minimum | | | | | | |
| Beam Cut Off Accuracy | 0.5% | 0.5% | 0.5% | 0.5% | 0.5% | 0.5% |
| Actual Energy (MeV/n) | | | | | | |
| Extracted | 315 | 1005 | 1000 | 1000 | 300 | 1000 |
| On Target | 307.7 | 969.1 | 1000* | 976.4 | 279.3 | 973.6 |
| Actual LET on Target (keV/μm) | 235.5 | 151.4 | 0.222* | 108.2 | 72.1 | 43.6 |
| Max. Dose Rate (Gy/min)/ Beam Size (cm x cm) | | | | | | |
| 20 x 20 | 6.2 | 4.0 | 0.6 | 2.5 | 3.0 | 2.8 |
| Total Dose (Gy) | | | | | | |
| Maximum | 50 | 50 | 50 | 50 | 50 | 50 |
| Minimum | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |

*Bragg Curve not available for these ions, as their range is too large.

Dosimetry notes

During this run we used the DBI and high-gain pixel chamber as part of routine operations. The DAQ was used to study beam purity (fragmentation) with scintillation counters.

We added a remotely operated rotational target stage, used primarily by physics users.

NSRL-6 was run behind RHIC polarized protons, making the pulse by pulse modulation (PPM) mode easy. The spill repetition rate, however, was determined by the PPM mode and was once every 5 seconds.

NSRL-6 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-3 | Cucinotta | Si, 0.3 GeV/n | 4 | 1.5 | 10-250 | 50 | 10 |
| | | Ti, 1 GeV/n | 4 | 0.0 | 0 | 0 | 0 |
| B-7 | Rabin | Fe, 1 GeV/n | 5.5 | 2.5 | 50-200 | 100 | 22 |
| | | Fe, 0.3 GeV/n | 5.5 | 0.0 | 0 | 0 | 0 |
| | | Ti, 1 GeV/n | 5.0 | 5.5 | 10-200 | 50-100 | 45 |
| B-44 | Durante Bettega Grossi | Fe, 1 GeV/n | 1.5 | 0.5 | 50 | 200 | 1 |
| | | Fe, 0.3 GeV/n | 4.0 | 3.5 | NA | NA | NA |
| | | Ti, 1 GeV/n | 2.5 | 2.0 | 23-150 | 100 | 12 |
| | | H, 1 GeV/n | 3.5 | 2.0 | 50-120 | 50-300 | NA |
| B-52 | Gewirtz | Fe, 1 GeV/n | 3.5 | 2.5 | NA | NA | NA |
| | | Si, 0.3 GeV/n | 3.5 | 1.0 | | | |
| | | Ti, 1 GeV/n | 3.4 | 3.0 | | | |
| B-64 | Vazquez | Fe, 1 GeV/n | 13.5 | 4.0 | 50-400 | 8-167 | 128 |
| B-65 | Vazquez | Fe, 1 GeV/n | 5.0 | 3.5 | 25-100 | 50-240 | 37 |
| | | Fe, 0.3 GeV/n | 2.0 | 2.0 | 25-100 | 10-100 | 30 |
| | | H, 1 GeV/n | 2.0 | 2.0 | 40-75 | 25-400 | 33 |
| B-73/ N-88 | Sutherland | Fe, 1 GeV/n | 3.2 | 3.5 | NA | NA | NA |
| | | Fe, 0.3 GeV/n | 1.5 | 1.5 | | | |
| | | Si, 0.3 GeV/n | 3.1 | 1.5 | | | |
| | | Si, 1 GeV/n | 1.5 | 1.5 | | | |
| | | Ti, 1 GeV/n | 2.6 | 4.5 | | | |
| N-80 | Gonda | Fe, 1 GeV/n | 4.5 | 4.0 | 10-200 | 100 | 21 |
| N-89 | Held | H, 1 GeV/n | 6.2 | 9.0 | 1-500 | 50 | 52 |
| | | Fe, 1 GeV/n | 7.0 | 9.5 | 1-500 | 50 | 45 |
| | | Ti, 1 GeV/n | 6.3 | 6.5 | 1-500 | 50 | 59 |
| N-90 | Bailey | Fe, 1 GeV/n | 2.0 | 2.0 | 100-400 | 35-170 | 40 |
| N-91 | Rydberg | Fe, 1 GeV/n | 4.0 | 3.0 | 5-100 | 10-50 | 25 |
| | | Fe, 0.3 GeV/n | 4.0 | 3.0 | 5-100 | 10-50 | 30 |
| N-99 | Zhao | Fe, 1 GeV/n | 1.5 | 0.5 | 10-100 | 50 | 3 |
| N-103 | Barcellos-Hoff | Fe, 1 GeV/n | 5.5 | 1.5 | 50-300 | 50 | 5 |
| N-104 | Weil/Ullrich | Fe, 1 GeV/n | 4.0 | 5.0 | 10-100 | 10-50 | 83 |
| N-105 | Bedford/Chatterjee | Fe, 1 GeV/n | 1.0 | 0.5 | 100-400 | 35-170 | 36 |
| | | Fe, 0.3 GeV/n | ? | 1.0 | 100-400 | 40-165 | 12 |
| N-115 | Bacher | Fe, 1 GeV/n | 4 | 2.5 | 50-300 | 50 | 82 |
| N-116 | Benton | Fe, 1 GeV/n | 12.0 | 0.0 | NA | NA | NA |
| | | Fe, 0.3 GeV/n | ? | 6.5 | | | |
| | | Si, 1 GeV/n | 12.0 | 12.5 | | | |
| N-120 | Redpath | Fe, 1 GeV/n | 2.0 | 2.0 | 1-50 | 10 | 40 |
| N-128 | Vazquez | Ti, 1 GeV/n | 12.3 | 12.5 | 40-75 | 10-100 | 50 |
| N-132 | Amundson | Fe, 1 GeV/n | 4.0 | 2.5 | 10-250 | 50 | 10 |
| N-134 | Chen | Fe, 1 GeV/n | 2.0 | 3.0 | 100-500 | 100 | 40 |
| N-136 | Britt | Fe, 1 GeV/n | 2.5 | 3.5 | NA | NA | NA |
| N-137 | Wilkins | Fe, 0.3 GeV/n | 9.1 | 8.5 | 150-15,000 | NA | NA |
| N-140 | Saganti | Fe, 0.3 GeV/n | 3.0 | 4.0 | NA | NA | NA |
| | | Si, 0.3 GeV/n | 3.0 | 3.0 | | | |
| | | Ti, 1 GeV/n | 3.0 | 3.5 | | | |
| N-145 | O'Banion | Fe, 1 GeV/n | 4.0 | 4.0 | NA | NA | NA |
| | | | | | | | |

| Exp. ID | Principal Investigator | Ion & Energy | Beam Time Approved | Beam Time Used | Dose Range (cGy) | Dose/Rate (cGy/min) | Number of Samples |
|---------------|------------------------|---------------|--------------------|----------------|------------------|---------------------|-------------------|
| N-146 | Wu | Fe, 0.3 GeV/n | ? | 2.0 | NA | NA | NA |
| | | Fe, 1 GeV/n | 3.0 | 3.5 | | | |
| | | Si, 0.3 GeV/n | ? | 3.0 | | | |
| | | Si, 1 GeV/n | ? | 3.5 | | | |
| N-151 | Posner | Fe, 1 GeV/n | ? | 6.0 | NA | NA | NA |
| | | Si, 0.3 GeV/n | ? | 4.5 | | | |
| Totals | | | 202.2 | 183.5 | 1-15000 | 10-400 | 1000+ |

NSRL-6 PARTICIPANTS, EXPERIMENTAL SAMPLES AND ENDPOINTS

| Exp. | Participants | Samples | Endpoints |
|------|--|---|---|
| B-3 | Heavy Ion Induced Chromosome Damage and Biomedical Countermeasures F. Cucinotta (PI) | Human Lymphocytes, Human Fibroblasts, and Chinese Hamster cells | Chromosome damage, structure effects on DNA double strand break induction and repair. |
| B-7 | Effects of Exposure to Heavy Particles B. Rabin (PI) | Sprague Dawley Rats | Behavioral paradigms and neurochemistry |
| B-44 | Influence of the Shielding on the Space Radiation Biological Effectiveness. M. Durante (PI) | Human lymphocyte, human cell lines (AG1522, H184B5, F5-1 M/10, SQ20B and SCC25) | Cell survival, chromosomal aberrations, DNA fragmentation |
| B-52 | Effect of Deep Space radiation on Human Hematopoietic Stem Cells. A. Gewirtz (PI) | Human bone marrow cells | DNA complex damages, DNA replication and apoptosis, gene expression |
| B-64 | CNS Damage and Countermeasures M. Vazquez (PI) | C57Bl/6 Mice | Behavioral alterations: locomotor activity |
| B-65 | Risk Assessment and chemoprevention of HZE-induced CNS damage M. Vazquez (PI) | NT2 and hNT human cell line | Apoptosis, toxicity, DNA damage, cell Cycle, geneexpression |
| B-73 | DNA damage clusters in low level radiation responses of human cells. B. Sutherland (PI) | T7 DNA, Human monocytes Supercoiled DNA | DNA damage cluster induction and repair at the molecular and cellular levels |
| N-80 | Comparison of Cell and Tissue 3D Models for Assessment of Genotoxic Damage by High Energy Charged Particles. S. Gonda (PI) | Normal & Transgenic fibroblast cells Normal & Transgenic epithelial cells | Mutation types and frequency induced in target genes at molecular level Dose relationships |
| N-88 | Complex Space Radiation-induced DNA damage Clusters in Human Cell Transformation: Mechanisms, relationships and Mitigation. B. Sutherland (PI) | Human normal fibroblasts | DNA damage cluster and transformation |
| N-89 | Induction of Bystander Effects by High LET Radiation in Cells K. Held (PI) | Human keratinocytes and fibroblasts | Micronuclei formation, expression of p21 and foci formation of γ H2AX |

| Exp. | Participants | Samples | Endpoints |
|-------------|---|---|--|
| N-90 | Genetic effects of siRNA knockdown of non-homologous end joining proteins in human lymphoblast cells S. Bailey (PI) | TK6 human lymphoblast cell. | Chromosome aberration formation, mutagenesis and telomere fusions. |
| N-91 | Repair of HZE-induced DNA Double Strand Breaks and PCC Breaks. B. Rydberg (PI) | HeLa cells, CHO cells and xrs6 cells | DSB determination, PCC and bystander effects |
| N-99 | Transformation of hTERT-immortalized human bronchial epithelial Cells by High Energy Heavy Ions. Y. Zhao (PI) | hTERT-immortalized human bronchial epithelial Cells and MEF cells | Cell survival and transformation |
| N-103 | Mechanism of HZE Damage and Repair in Human Epithelial Cells. M. Barcellos-Hoff (PI) | HMEC 184 | Survival assays, Gene expression, Immunostaining |
| N-104 | Radiation Leukemogenesis M. Weil/R. Ullrich (PI's) | CBA/CaJ strain mice | Determination of RBE for the induction of AML using slope constants |
| N-105 | Predicted and Observed Dose-Responses for Simple and Complex Chromosomal Aberrations after Exposure of Human Cells to HZE Radiations: Effects of Beam Filtration. A. Chatterjee/J. Bedford (PI's) | GM2149 low passage normal human fibroblasts | FISH Chromosome painting, chromosomal aberrations |
| N-115 | A Novel Biodosimetry Method for Monitoring Radiation Induced Mutations. J. Bacher (PI) | Mice, HCT116, HEC-59 and MEF cells from MHL1 and MSH2 deficient mice | Multiplex Assays, Mutational Load Profiles |
| N-116 | Benchmark Analysis and Evaluations of Materials for Shielding/Radiation Shielding Properties of Multifunctional Spacecraft. E. Benton (PI) | Assorted Target Shielding Materials | Beam measurements using TEPC, CR-39 PNTDs, and Liulin MDU |
| N-120 | Dose response for the ⁵⁶ Fe ²⁶ (964MeV/n) induced neoplastic transformation in vitrp L. Redpath (PI) | CGL1 (HeLa x skin fibroblast hybrid) | Neoplastic Transformation <i>In Vitro</i> |
| N-128 | NASA Summer School M. Vazquez (PI) | NT2 and hNT human cells, TK6, human lymphocytes Track detectors, mice | Apoptosis, toxicity, chromosomal aberrations, hematological changes, physics studies |
| N-132 | Functional genomic responses to HZE particles S. Amundson (PI) | p53-wild-type TK6 cell, p53-null NH32 cell line | Gene expression, colony formation, FACS. |
| N-134 | DNA damage responses induced by HZE particles in human cells. D. Chen (PI) | Human skin fibroblasts (HSF42) | Cytotoxicity, DNA damage (H2AX), gene expression, bystander effect. |
| | | | |

| Exp. | Participants | Samples | Endpoints |
|-------------|---|---|---|
| N-136 | IR-induced damage responses and repair requirements in Arabidopsis A. Britt (PI) | Arabidopsis | Growth-responses and formation of H2AX foci, somatic loss of heterozygosity |
| N-137 | Heavy Ion Shielding Studies on Multi-Functional Nano-Materials and Composites D. Wilkins (PI) | Nano-composite samples | Cross-section and fragmentation studies. Mechanical testing of composites. |
| N-140 | Heavy Ion Particle Impact on Simulated Martian Regolith P. Saganti (PI) | Martian regolith targets with simulated Martian | Neutron production flux measurements |
| N-145 | HZE Radiation Effects on Neuroinflammation K. O'Banion (PI) | C57Bl/6 mice. | Changes in cytokine profiles in brain areas and histopathology. |
| N-146 | Cytogenetic study of heavy ion-induced chromosomal damage in human cells H. Wu (PI) | Human lymphocytes. | Chromosomal aberrations. FISH |
| N-151 | MSL/RAD Technology Demonstration Model Characterization A. Posner (PI) | Solid state detectors | Hardware and software calibration |

List of personnel that participated in the planning, organization and execution of NSRL-6 run

BNL Management:

- Laboratory Director: **Praveen Chaudhari**
- Associate Director for High Energy and Nuclear Physics: **Samuel Aronson**
- Associate Laboratory Director for Life Sciences: **Helene Benveniste**

NASA Management:

- JSC: **Frank Cucinotta, Frank Sulzman, Barbara Corbin**

Scientific Advisory Committee:

- **Betsy Sutherland** (Chair), BNL
- **Richard Setlow**, BNL
- **Kathy Held**, MIT
- **Les Braby**, PNL
- **Charles Geard**, Columbia University
- **John Gatley**, BNL

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 ESHQ: **Ed Lessard**
- ESHQ Division Head: **Ray Karol**
- ESH Coordinator: **Asher Etkin**
- Facility Support Representative: **Chuck Schaefer / Henry Kahnhauser**
- Environmental Coordinator: **Joel Scott**
- Training and Procedures Manager : **John Maraviglia**
- Main Control Room: **Peter Ingrassia**
- Work Control Manager: **Peter Cirnigliaro**
- BNL Laser Safety Officer: **Chris Weilandics**
- Experimental Safety Review Committee: **Yousef Makdisi (Chair)**
- Radiation Safety Committee: **Dana Beavis (Chair)**
- Accelerator Safety Review Committee: **Woody Glenn (Chair)**
- ALARA Committee: **Chuck Schaefer (Chair)**
- Associate Chair for ES&H/Q.A: **E. Lessard**
- 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: **David Phillips**
- Liaison physicist: **Adam Rusek**
- 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**
- **AGS MCR Operation Coordinators:**
 - Jim Jamilkowski**
 - Sanjee Abeytunge**
 - Jennifer Kozak**
 - Brian van Kuik,**
 - Travis Shrey**
- AGS Electricians led by **Bill Softye**
- AGS Riggers led by: **Nick Cipolla**
- Carpenter and Welder Support Service and Technical Support led by: **Roger Hubbard**

Dosimetry:

- **Adam Rusek**
- **I-Hung Chiang**
- **Kin Yip**
- **Peter Oddo**
- **Bart Frak**

Medical Department:

NASA LTSF TEAM:

- **Medical Liaisons: Marcelo E. Vazquez, Peter Guida**
- **Technical support: Bea Pyatt, Adele Billups, Laura Thompson, Angela Kim**
- **Secretarial support: Fran Capasso**

- Dept. Chair: **Helene Benveniste**
- Building Manager: **Chris Harris**
- Administration: **Denise White and Donna Russo**
- Animal Care Facilities: **Maryann Kershaw, Kerry Bonti, Patricia Leone**
- Training Coordinator: **Ann Emrick**
- **RCD**
 - Kay Conkling
 - Dennis Ryan
 - Deana Buckallew
 - Jim Williams
 - Bob Colichio

Plant Engineering:

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

Biology Department:

- Chairman: **Carl Anderson**
- Biology Liason: **Betsy Sutherland**
- Technical Support: **Mamta Naidu, Debasish Roy, Stefan Tafrov**
- Cesium Source Manager: **Richard Sautkulis**