Lighting FIRES – Full Interplanetary Radiation Environment Simulation

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Workshop on Radiation Monitoring on the International Space Station
2-4 September 2002
Paris, France

Strategic Program Plan Elements

- **Construct and operate ground facilities to simulate space and planetary radiation environments**
- Acquire essential biomedical data
- Develop shielding materials
- Incorporate biomedical and materials requirements into mission design

US Radiation Facilities

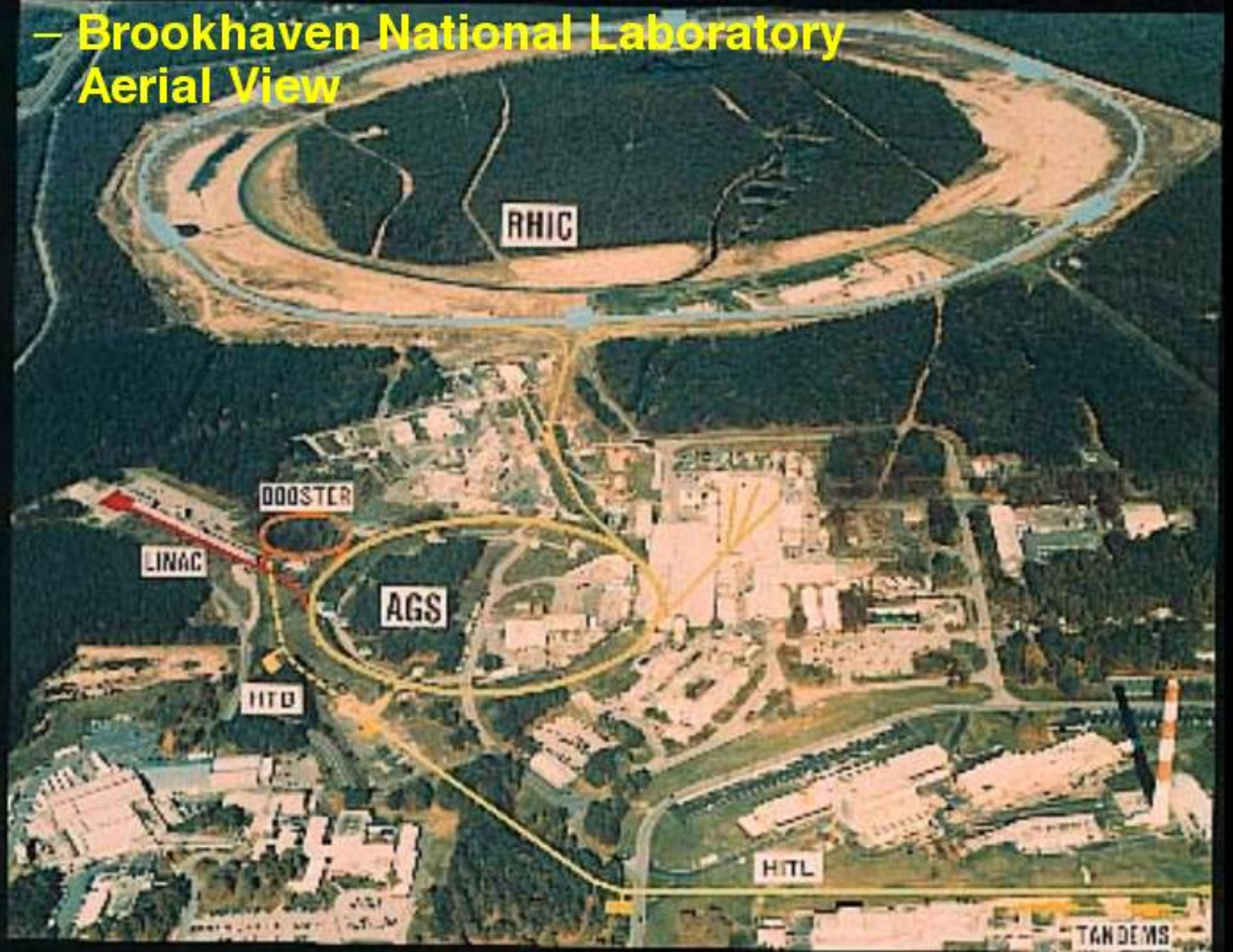
- **Brookhaven National Laboratory**
  - **Alternating Gradient Synchrotron**
  - **Booster Synchrotron**
- Loma Linda University Medical Center

AGS RUNS

RUN	DATES	BEAM CHARACTERISTICS		
		Beam	Energy (MeV/u)	LET (keV/μm)
BNL-1	Oct 95	^{56}Fe	1087	150
BNL-2	Oct 96	^{56}Fe	1060	148
			580	173
BNL-3	Oct 97	^{56}Fe	1060	148
			565	177
BNL-4	Apr 98	^{197}Au	10800	1445
	May 98	^{56}Fe	1060	148
			565	177
BNL-5	May 99	^{56}Fe	1060	148
			561	177
BNL-6	Nov 99	^{56}Fe	1046	148
		^{28}Si	1182	42
BNL-7	Jan 01	^{56}Fe	1046	148
BNL-8	Apr 02	^{56}Fe	~1000	~150
		^{28}Si	~600	~50
			~1000	~43

ID	Participants:	Beam Hours	Samples
BNL-1	41 scientists from 12 institutions: 13 PIs, 3 post-docs, 3 graduate students, 1 HBCU	100.5	894
BNL-2	63 Scientist from 18 institutions: 18 PI s, 7 Co-PI, 5 post-docs, 3 graduate student	129	1400
BNL-3	64 Scientist from 22 institutions (1 international): 22 PI s, 9 Co-PI, 2 post-docs, 2 graduate student	149	1802
BNL-4	65 Scientist from 21 institutions (1 international): 21 PI s, 7 Co-PI, 1 post-docs, 3 graduate student	190.5	1183+
BNL-5	64 Scientist from 14 institutions (1 international): 17 PI s, 4 Co-PI, 1 post-docs, 1 graduate student	190	998+
BNL-6	55 Scientist from 16 institutions (1 international): 15 PI s, 4 Co-PI, 3 post-docs	193	1322+
BNL-7	81 Scientists from 24 institutions (5 international); 11 Pis, 6 Co-Pis, 1 Postdocs, 4 students	183	1654+
BNL-8	19 Pis from 14 institutions (2 international)	162.5	

– Brookhaven National Laboratory Aerial View



NASA Irradiation Facilities at Brookhaven National Laboratory

RELATIVISTIC HEAVY ION COLLIDER (RHIC)

AGS Radiobiology Experiments

AGS EXTERNAL BEAMS

BOOSTER

200 MeV LINAC

ALTERNATING GRADIENT SYNCHROTRON (AGS)

200 ft

HEAVY ION TRANSFER LINE

TANDEM VAN DE GRAAFFS

Operating Parameters

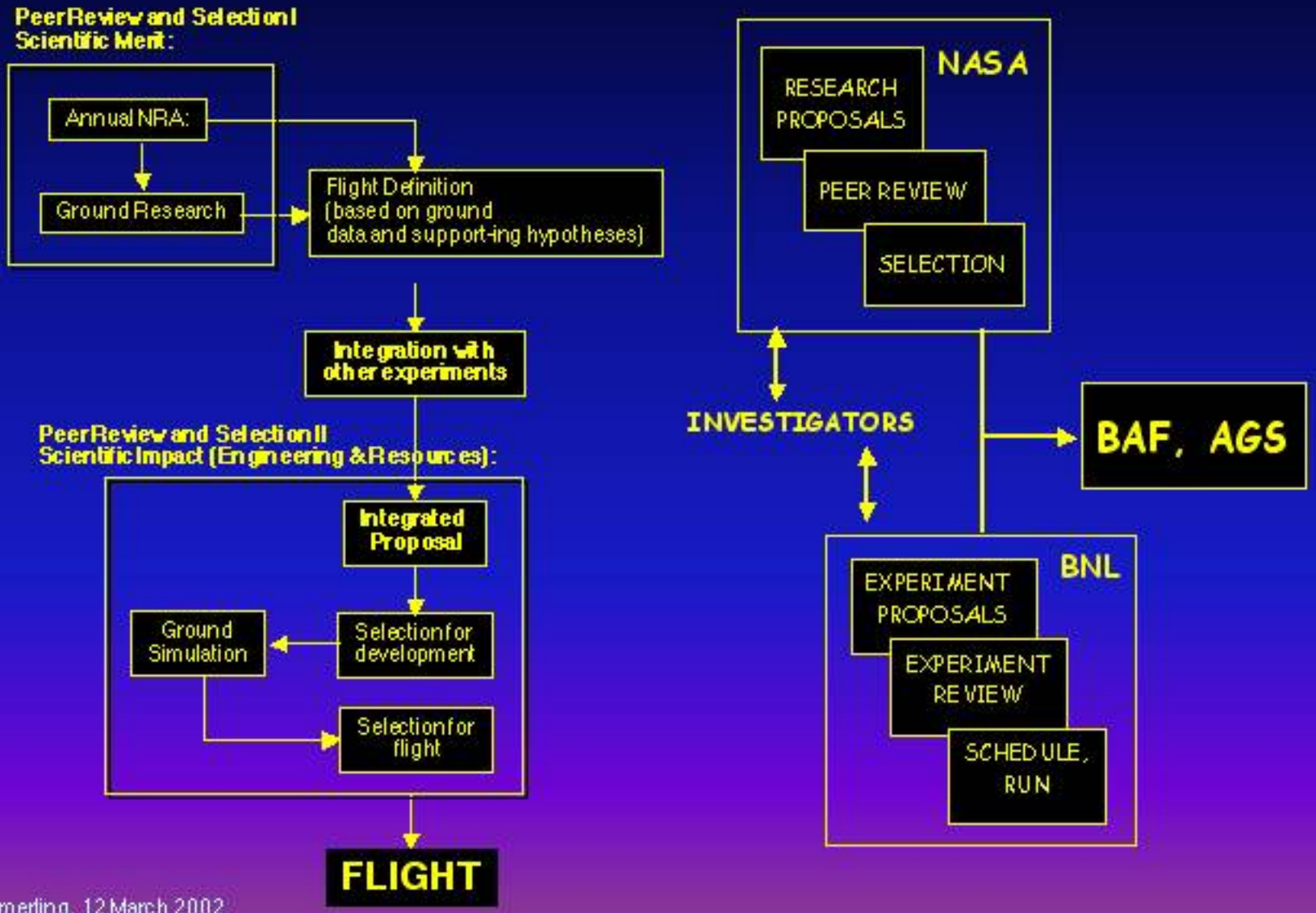
AGS Operating Parameters

Minimum useful heavy ion energy:	0.6 GeV/u
Maximum heavy ion energy:	14.5 GeV/u
Fluence (particles/cm^2/spill)	
Maximum Extracted	3.5×10^9
Maximum On target	3.5×10^9
Spill rate (spills/min)	30
Maximum uniform beam spot diameter (cm)	7.5
Spill length (msec)	500
Beam cut off length.	<1%
Maximum measured dose rate (Gy/min)	15 (0.5 Gy/spill)

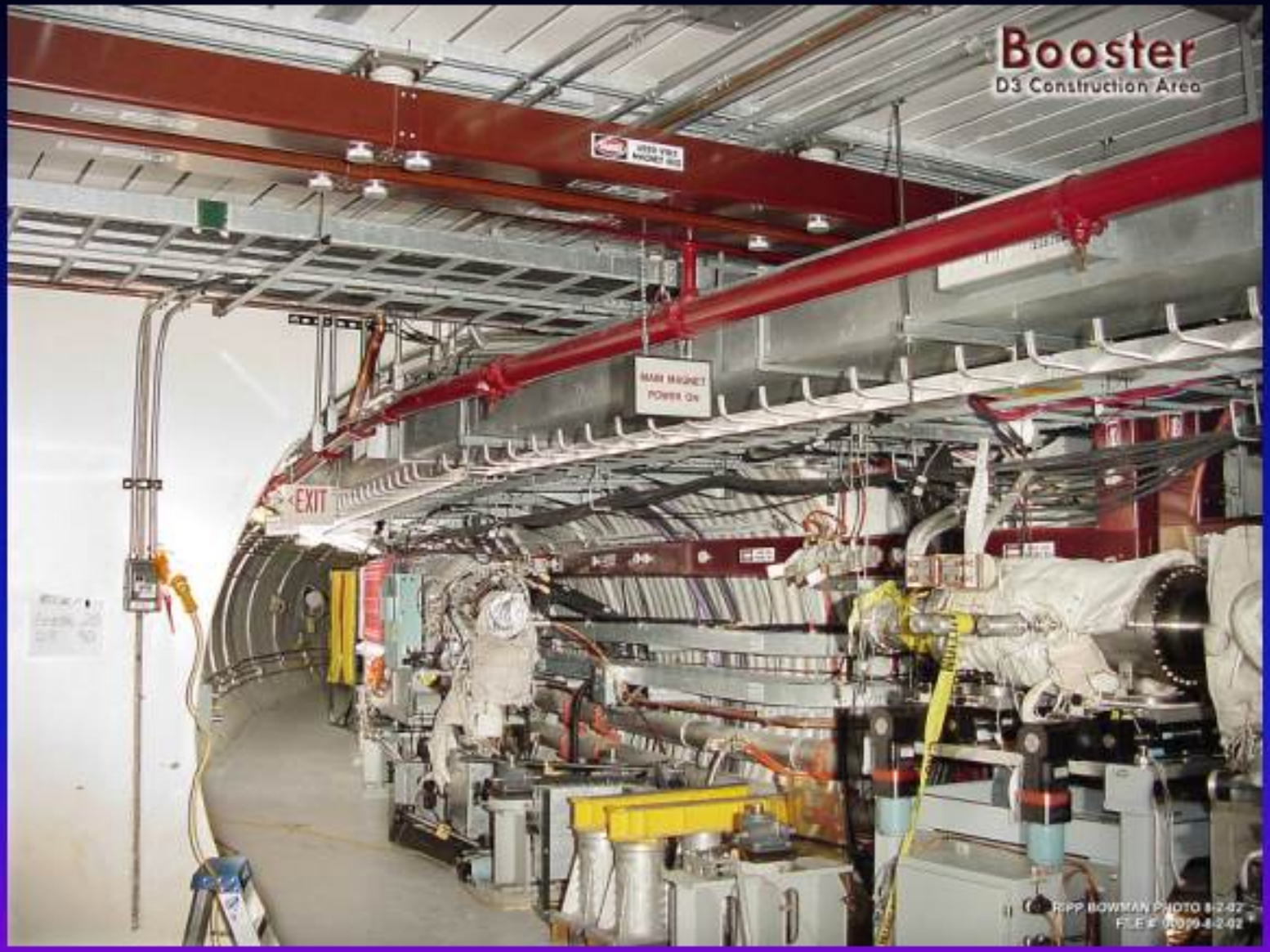
Booster Operating Parameters:

SPECIES (Z,A)	ENERGY RANGE (MeV / nucleon)	TYPICAL DOSE RATES (Gy/min)
H(1,1))	100-3070	54-16
Si (14,28)	90-1230	114-31
Fe(26,56)	100-1100	146-43
Cu(29,63)	100-1040	n.a.
Au(79,97)	40-300	n.a.

Experiment Review and Scheduling



Booster Synchrotron at BNL
(Artist's Conception of Extracted Beam)


Booster
D3 Construction Area
EXIT
MAIN MAGNET
POWER ON

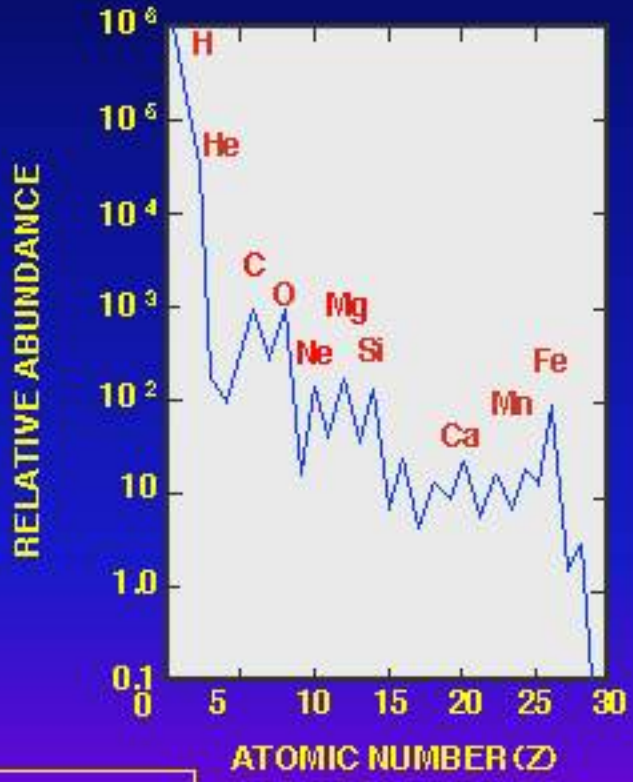
BAF - 1 August 2001

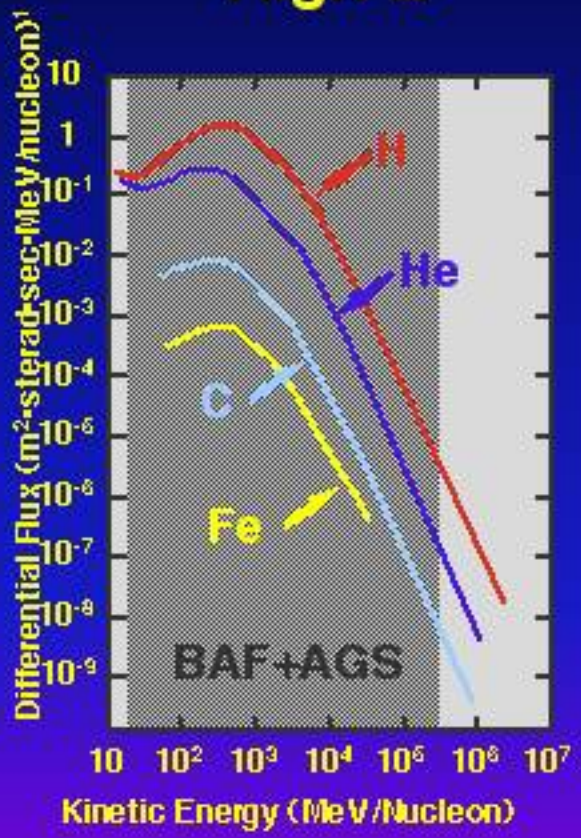
Why Ground-Based Research?

- Full range of particles and energies can be obtained at particle accelerators
  - mixed radiation fields can be designed to simulate particular space radiation characteristics
- Cost effective research leading to timely, statistically significant results
  - Hypotheses can be tested without constraints and costs imposed by flight qualification
  - Frequency of experiments is significantly higher
  - Access significantly easier
- Allows correlated physics and biology investigations
  - Can measure biological effectiveness of shielding designs
  - Intercomparison and calibration of dosimeter responses
  - Correlation of dosimeters with biological responses
- Identify critical experiments for spaceflight validation
  - Benchmark physics and biology relevant to human risk
  - Pre-qualify flight experiments involving radiation

Galactic Cosmic Rays

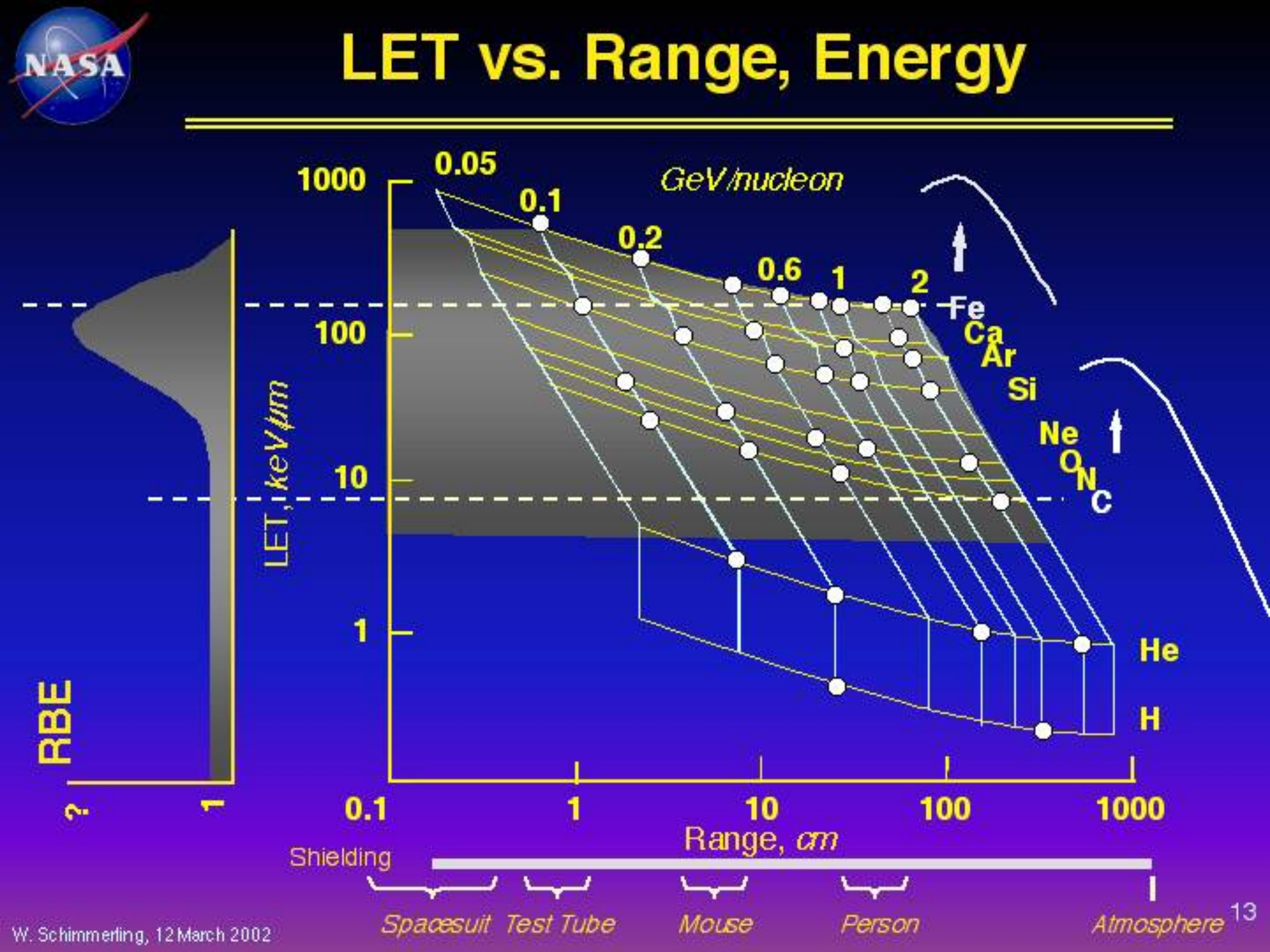
"HZE": High Z + High E





~85% protons
~14% helium
~1% heavier particles

LET vs. Range, Energy



Projectiles and Energies

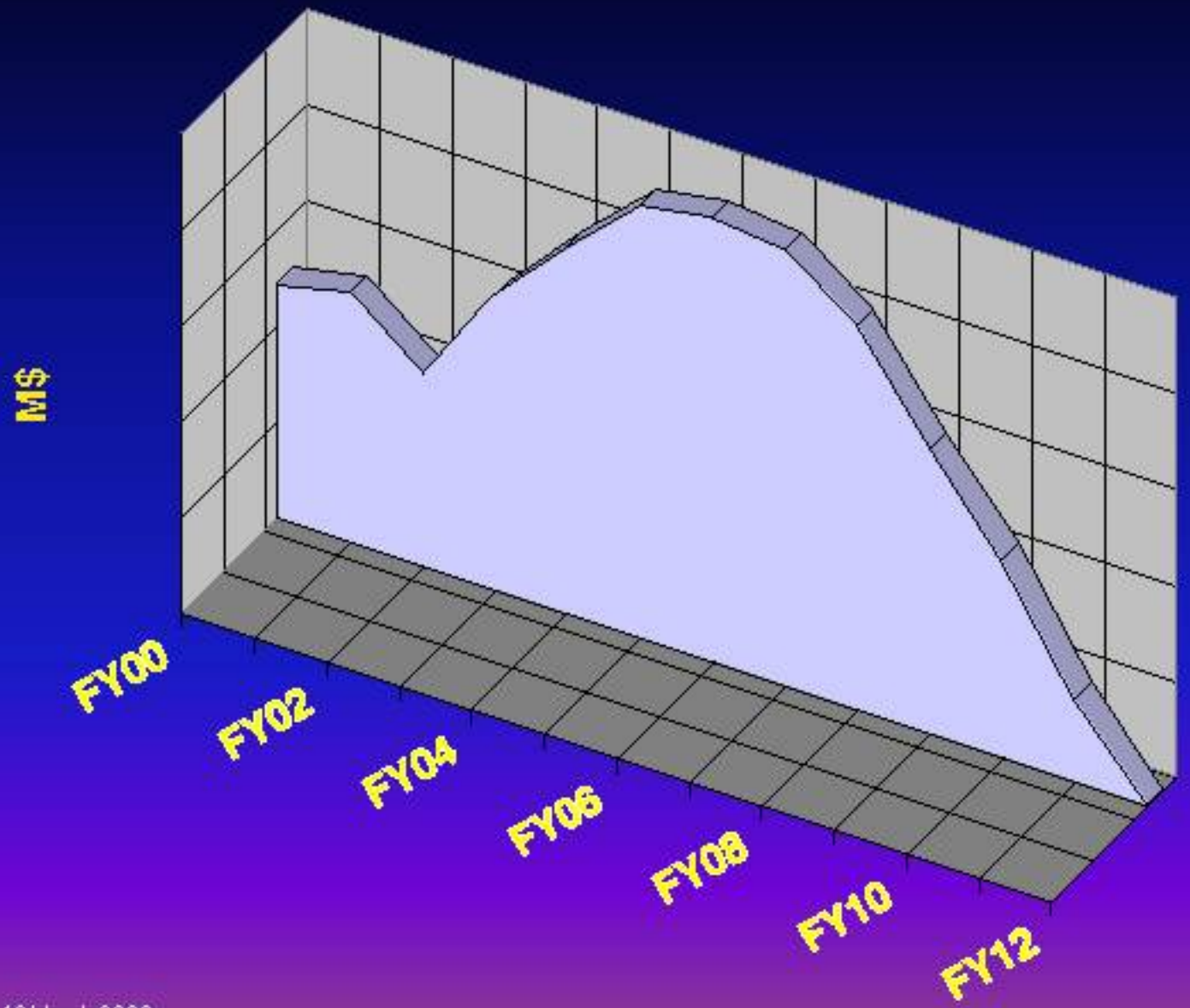
ε_p (GeV/u)	(Z,A)										
	H	He	C	N	O	Ne	Si	Ar	Ca	Mn	Fe
0.1		●	●		●		●				●
0.2	●	●	●X	X	●X		●X	X			●X
0.4			●		●		●	●			●
0.6		●			●	X	●X				●X
0.8							●	●			●
1.0	●										●X
1.5		●	●		●		●	●	●	●?	●
2.0	●				●						●
5.0	●				●		●				●

- ● **Required data**
- X **Partial data available**

Space Radiation Initiative
SCOPE

- **Generate knowledge** required to assure that humans can live and work in space without exceeding established working limits for radiation risk at required statistical confidence levels
  - Train a generation of radiobiologists to participate in generating breakthroughs in science and leveraging them for NASA
  - Assure 3 180-day missions in LEO with 95% confidence (or similar requirement)
  - Assure one 1000-day Mars mission with 95% confidence (or similar requirement)
  - Eventually: assure permanent presence in space -- anytime, anywhere
- **Predict risk** (critical path)
  - mechanistically based predictions of cancer in humans
  - behavorial/ neurological functional impact
  - germ cell impact
  - Interaction of radiation sensitivity with other spaceflight factors
- **Reduce uncertainty**
  - biomarkers to predict individual risk
  - biological and physical data base accessible at AGS, BAF
  - critical experiments on ISS, Mars, Free Flyers to validate predictive models
- **Develop Rational Intervention**
  - optimized shielding methodologies
  - biology breakthroughs
  - criteria for medical surveillance and treatment
  - genetic screening and counseling

Space Radiation Protection Initiative



BAF/AGS Utilization

	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09
Solicitations :								
Buildup to 50 biology PI	◇—------◇							
NRA schedule: yearly	◇	◇	◇	◇	◇	◇	◇	
Commissioning of BAF facility		◇						
Beam Use								
300 hours/yr		◇-----◇						
600 hours/yr			◇----------◇					
1200 hours/yr						◇----------◇		
AGS operation (300 - 600 h/y)	----------◇							

OMB Approval No. 2700-0087

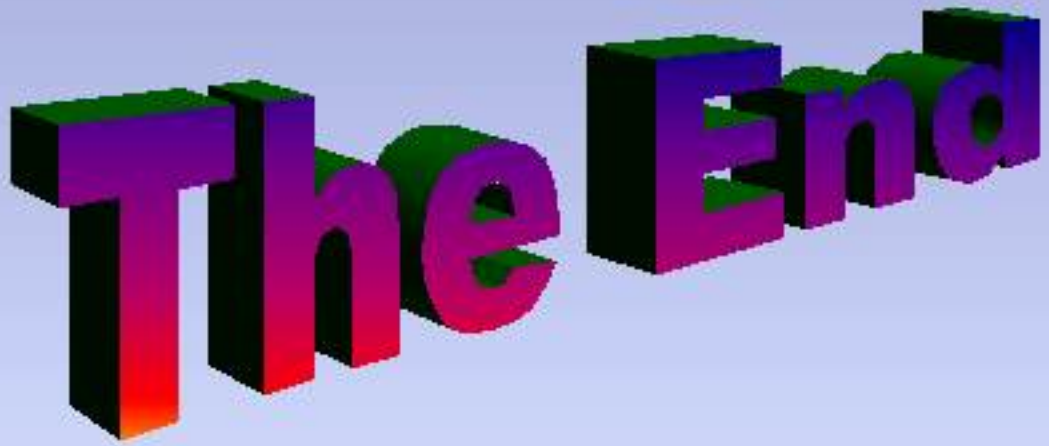
National Aeronautics and Space Administration
Office of Biological and Physical Research
Washington, DC 20546

Research Announcement

Research Opportunities
for
Ground-Based Research
in
Space Radiation Biology
and
Space Radiation Shielding Materials

NRA 02-OBPR-02
August 30, 2002

NASA Research Announcement Soliciting Research Proposals for
the Period Ending March 30, 2004


The End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