BNL Radioisotope Research & Production Program Overview

Operations Review

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BROOKHAVEN NATIONAL LABORATORY

Radioisotope Program Components

- Isotope Production and Distribution at BLIP
  - Distribution for sale; process & target development to improve quality & yield.
  - Sr-82/Rb-82 for human heart scans with PET
  - Ge-68 for calibration of PET devices
  - Zn-65 tracer for metabolic or environmental studies
- Radioisotope R&D
  - Cu-67, for cancer therapy applications
  - Y-86 for cancer imaging
  - Fe-52 labeled nanoparticles for combined PET/MRI imaging
- Training
  - Support (space, equipment, faculty) for DOE funded Nuclear Chemistry Summer School, an undergraduate course in nuclear and radiochemistry
- Radiation damage studies
  - Target and magnet materials for future high power accelerators, collaboration with BNL Physics & ES&T Departments
  - Materials for Facility Rare Isotope Beams (FRIB), collaboration with BNL Magnet Division and ES&T Department

BNL Accelerator Complex (AGS=Alternating Gradient Synchrotron, RHIC=Relativistic Heavy Ion Collider)

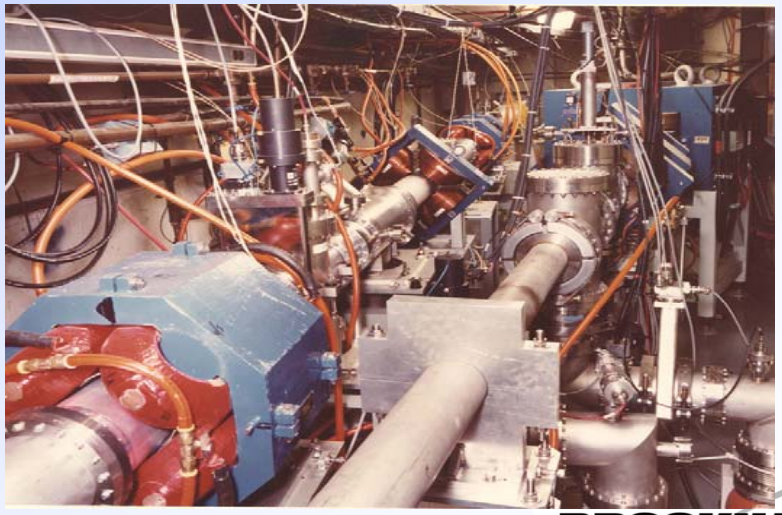
Facility Description

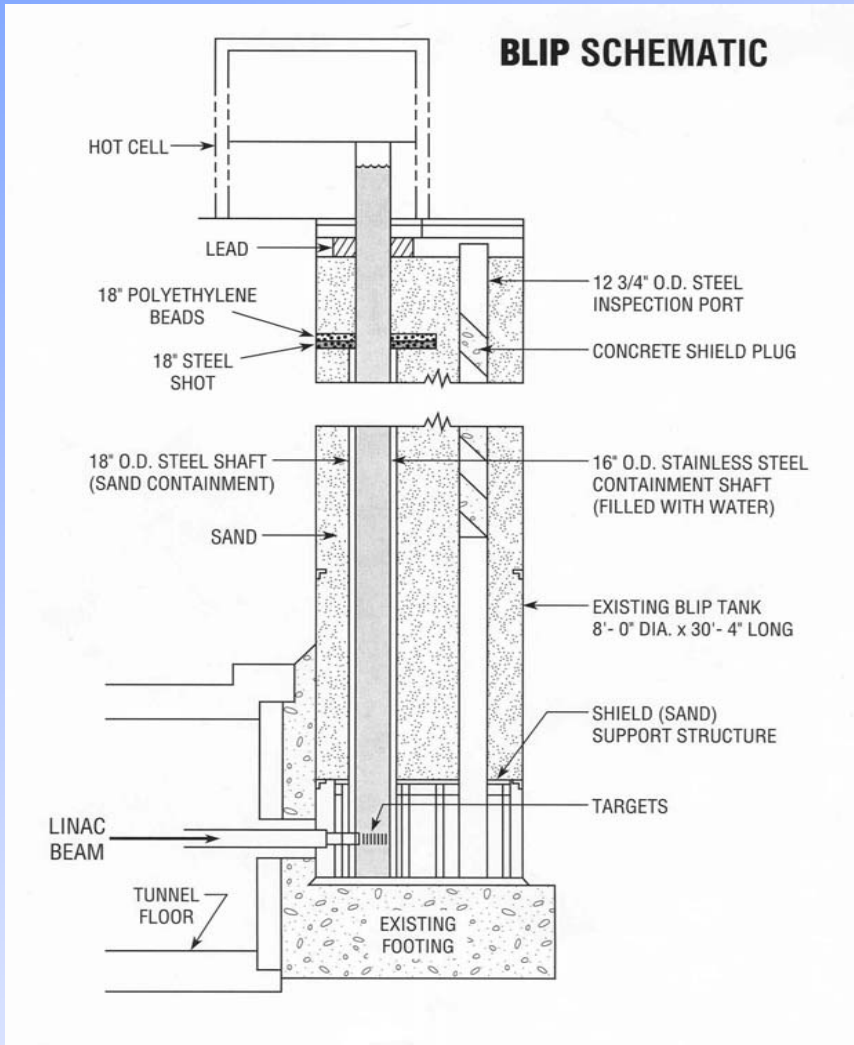
- The Brookhaven Linac Isotope Producer (BLIP) was the world's first facility to seriously exploit the isotope production capabilities of a high energy proton accelerator.
  - The use of higher energy particles allows the use of relatively thick targets, where the large number of target nuclei can compensate for the generally smaller nuclear reaction cross sections compared to low energy reactions.
  - The BLIP, built in 1972, utilizes the excess beam capacity of the 200 MeV proton Linac that injects into larger synchrotrons (Booster, AGS, RHIC) at BNL. A 30m long transport line delivers the protons to a shielded target area for radioisotope production. The facility has been upgraded twice, in 1986 and 1996.
  - The target area consists of an underground 2.44m diameter tank containing sand shielding, a water filled 40cm diameter shaft, 9.2m high, and a 20cm diameter inspection shaft.
  - The target assembly is immersed at the bottom of the shaft and cooling water is forced individually past the faces of the target disks.

Brookhaven LINAC Isotope Producer (BLIP)

The LINAC supplies protons to the Booster for nuclear physics. Excess pulses (~85%) are diverted to BLIP. Energy is incrementally variable from 66-202 MeV.

The BLIP beam line directs protons up to 105μA intensity to targets; parasitic operation with nuclear physics programs




BLIP SCHEMATIC
HOT CELL
LEAD
18" POLYETHYLENE BEADS
18" STEEL SHOT
12 3/4" O.D. STEEL INSPECTION PORT
CONCRETE SHIELD PLUG
18" O.D. STEEL SHAFT (SAND CONTAINMENT)
SAND
16" O.D. STAINLESS STEEL CONTAINMENT SHAFT (FILLED WITH WATER)
EXISTING BLIP TANK 8'- 0" DIA. x 30'- 4" LONG
SHIELD (SAND) SUPPORT STRUCTURE
TARGETS
LINAC BEAM
TUNNEL FLOOR
EXISTING FOOTING

BLIP Operating Parameters

- Energy – incrementally variable: 66, 93,118,139,161,181, 202 MeV
- Maximum pulse current 37mA, pulse rate 6.67 Hz, pulse width 425μs
- Maximum integrated current - 105μA, typical integrated current (parasitic mode) -80μA
- Pulse to pulse control of energy and intensity at the Linac allows simultaneous operation with polarized protons
- Power – 7.4MW instantaneous, 21 kW integrated
- Target capacity – up to 8 simultaneously, dependent on beam energy & target thickness (4 typical)

The Target Processing Laboratory

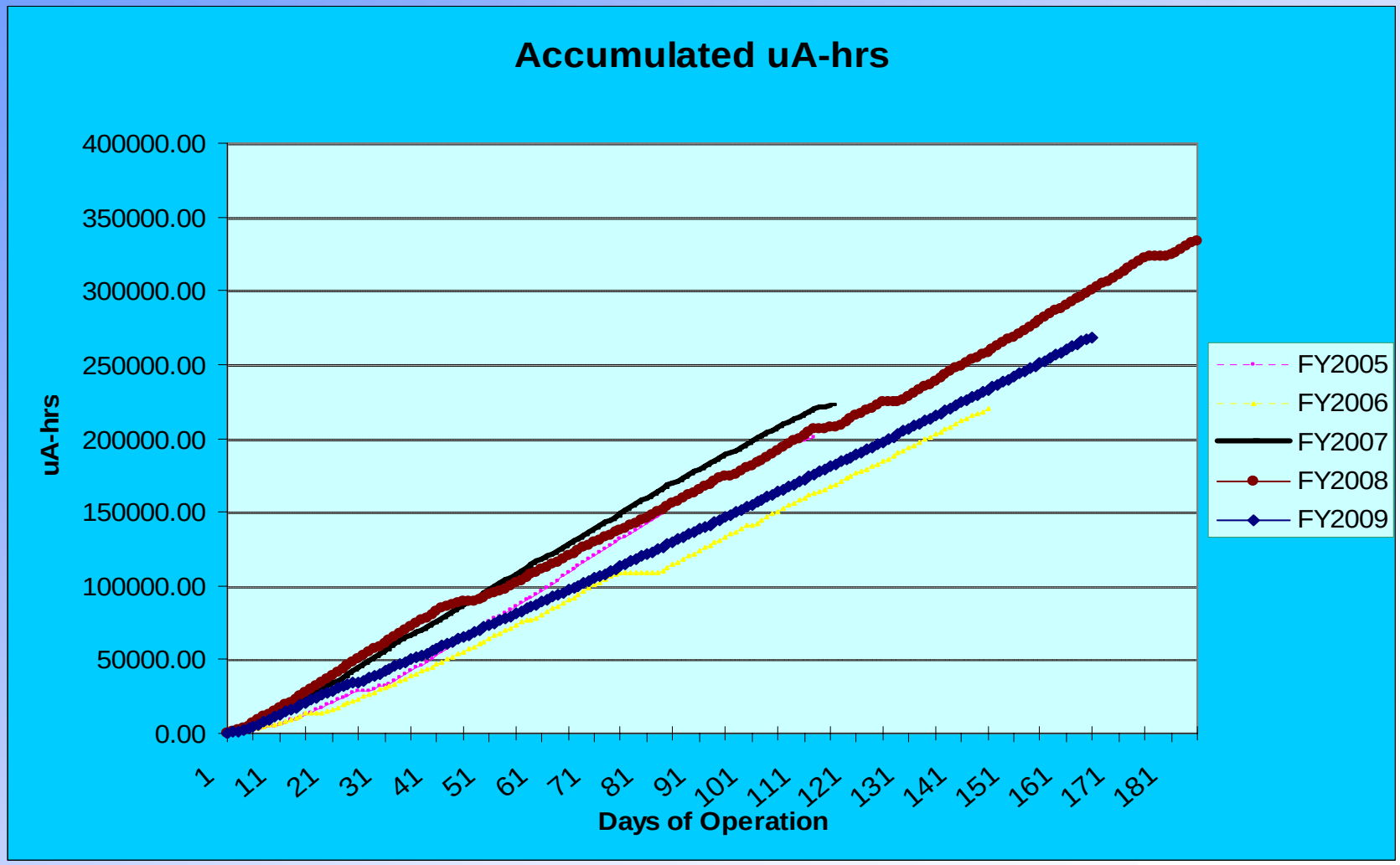
- After irradiation all targets require chemical processing to separate the desired isotope from many others coproduced and from the bulk target material. We have:
  - 9 hot cells
  - 8 radiochemistry development labs
  - Instrumentation lab for radionuclide and chemical assays
  - radwaste handling and shielded storage facilities for both liquids and solids
  - Staff machine shop
  - For human use isotopes we maintain current good manufacturing practice (CGMP) registration with FDA

View of several processing hot cells

Operating modes

- Schedule – Due to high Linac operating costs BLIP generally runs in a parasitic mode, sharing pulses (~85% share), and costs (~30% share) with the driver polarized proton nuclear physics programs at RHIC. The schedule and duration of Linac operation is largely determined by the plans and funding of the nuclear physics experiments, not isotope production needs.
- Dedicated production to supplement shared Linac use with polarized protons has been become possible with increased isotope revenue
- Production coordination with other sites, mostly with Los Alamos, but also S. Africa, & Russia has helped year round availability of longer lived, high value isotopes, such as Sr-82 and Ge-68. This is not possible with short lived, low value research isotopes.
  - We also share procedures, targets and shipping casks with LANL.

Integrated beam intensity 2005-2009



BLIP Operations summary

Item	FY2007	FY2008	FY2009
Run time (h)	1910	3955	3937
Average intensity (μA)	85.7	83.9	70.2
Total beam current (μAhr)	163,797	331,662	276,247
Reliability %	100	99.2	99.8

Scientific Approach

- Nuclear physics issues
  - Investigate proper nuclear target by determination of nuclear excitation functions for desired isotope and probable impurities by literature search, calculation or direct measurement
- Target design
  - Pick material that has appropriate physical and chemical properties (density, isotopic abundance, solubility, purity, availability, low corrosivity), good mechanical and thermal properties (high melting and boiling points, high thermal conductivity, high stability, low vapor pressure)
- Radiochemistry development
  - Design chemical separation scheme to yield desired isotope in high chemical and radiochemical purity. Ion exchange chromatography, solvent extraction and distillation techniques used
  - Develop assay methods for radiopurity by gamma ray spectroscopy and/or beta counting by liquid scintillation
  - Develop labeling methods in template systems, for example by linking to monoclonal antibodies, as a final test of product usefulness
- Package and ship
  - Assorted sizes of DOT approved containers are used for radioisotope transport both domestically and internationally

Isotope Program Staff

- Leonard Mausner,PhD - program management, target design
- Suresh Srivastava PhD - strategic planning, radiophamaceutical R&D
- Dmitry Medvedev PhD – isotope R&D, detector manager
- Cleveland Dodge PhD – QC manager, isotope R&D
- Slawko Kurczak BS – hot cell supervisor, isotope processing, staff shop supervisor
- George Meinken MS – isotope assay, hot cell maintenance
- Elizabeth Korach MS - isotope processing, hot cell maintenance, waste disposal
- Joseph O Conor AA – hot cell & BLIP maintenance, isotope processing, waste disposal
- Henry Schnakenberg BS – BLIP operation & maintenance
- James Bullis MS - QA cGMP manager, ESH coordinator, building manager
- Engineering assistance from CAD – S. Bellavia mechanical, A. Pendzick civil, M. Wilenski instrumentation, C. Theisen software

Activities during BLIP down time

- Dispensing of long lived isotopes (eg. Ge-68, Zn-65, Ni-63, Fe-55) from inventory continues year round
- Waste disposal push
- BLIP upgrades, and maintenance
- Hot cell suite upgrades, maintenance, cleaning and painting interiors
- Isotope R&D effort with substitute tracers (if possible)
- Staff vacation

Budget Distribution

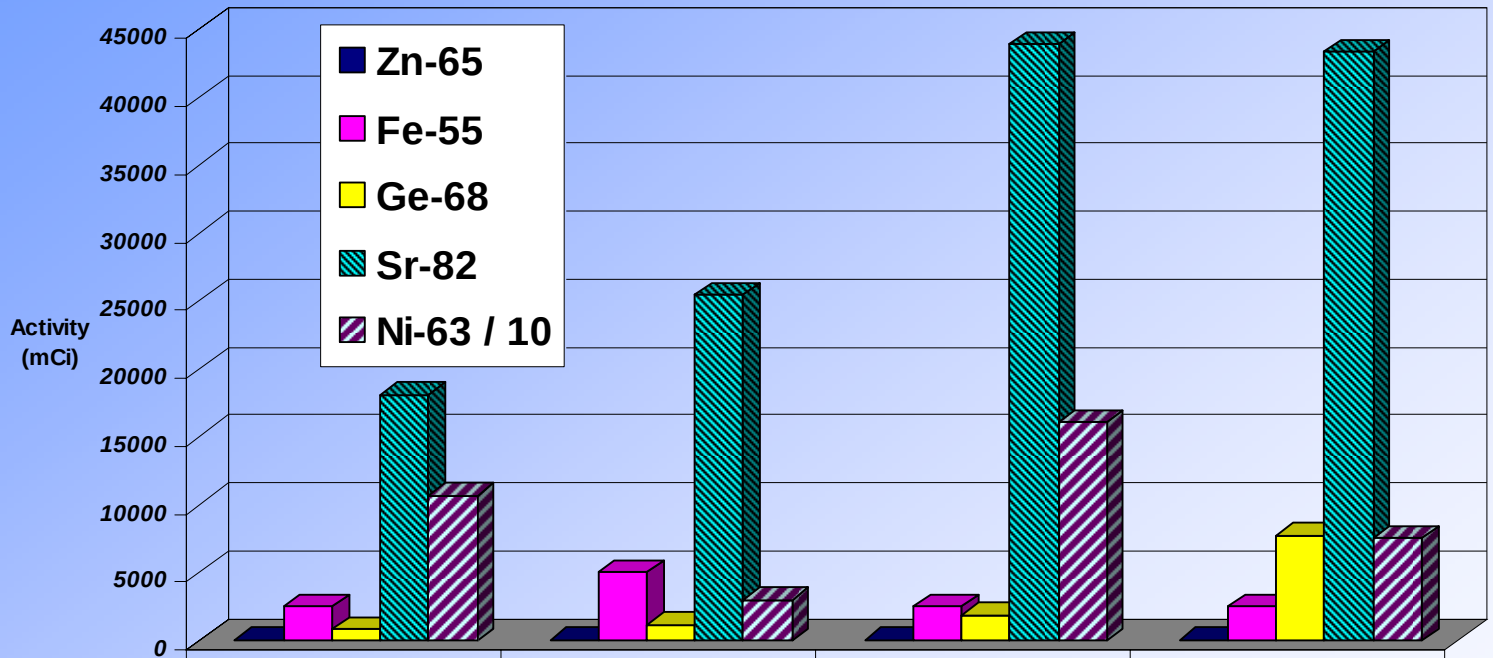
Item	FY2009 Expense ($K)	FY2010 Projected ($K)
BLIP infrastructure	503	500
Hot cell infrastructure	2947	2808
Isotope Production	1136	2283
Cu-67 R&D	123	426
Y-86 R&D	64	302

Present Isotope Distribution List

Isotope	Half- life	Typical application
Be-7	53.3d	γ source
Zn-65	244d	Zn tracer
Ge-68/Ga-68	271d/68m	PET calibration
As-73	80.3d	As environmental tracer
Sr-82/Rb-82	25.5d/75s	PET studies of heart
Y-88	106.6d	Y-90 tracer, γ source
Tc-95m	61d	Tc tracer

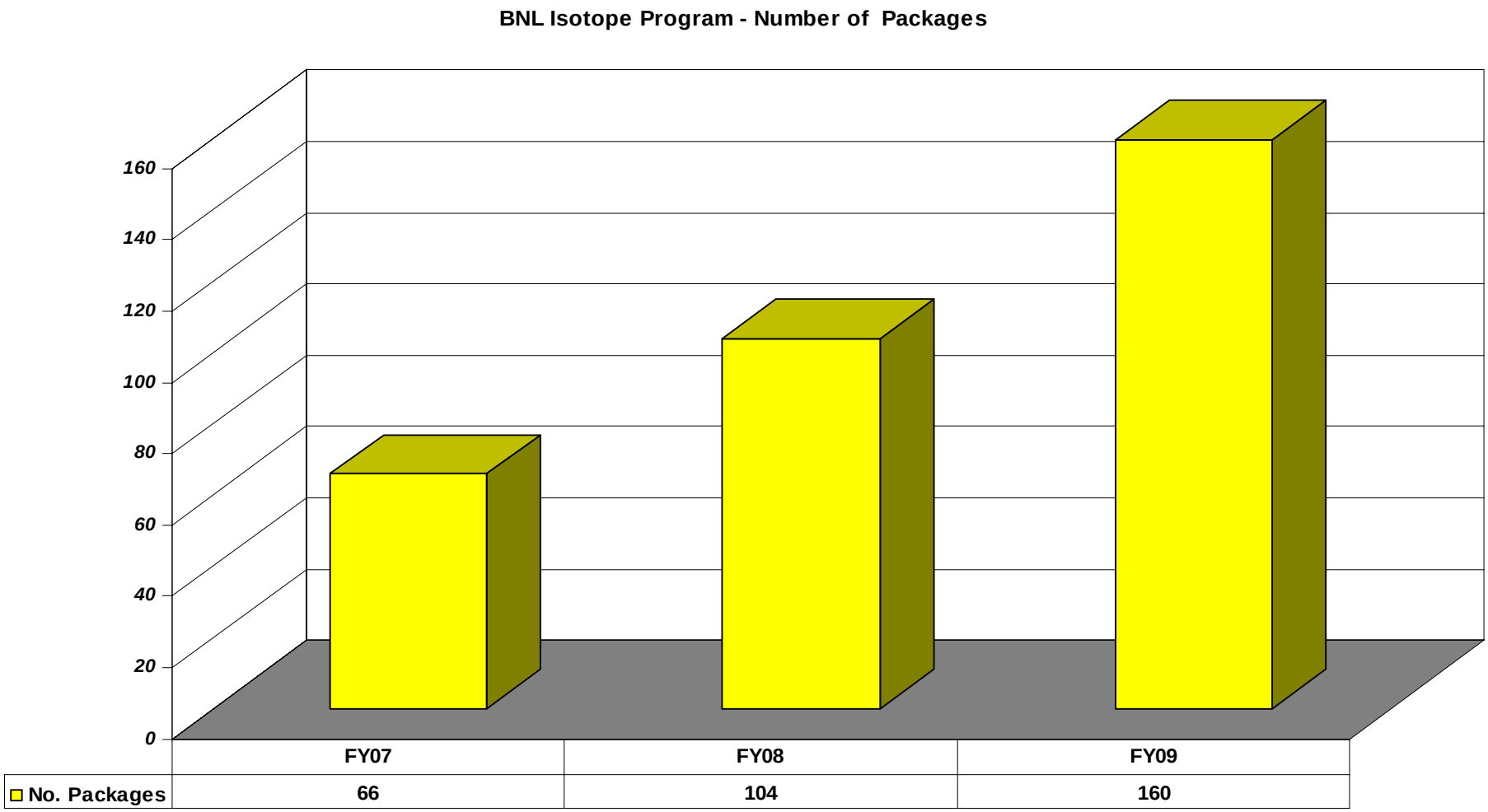
*Previously developed Na-22, Mg-28, Sc-47, Fe-52, Co-55, Rb-81, Tc-96, Ru-97, Cd-109, Sn-117m, Xe-122, Xe-127, Pb-203

Isotope Sales

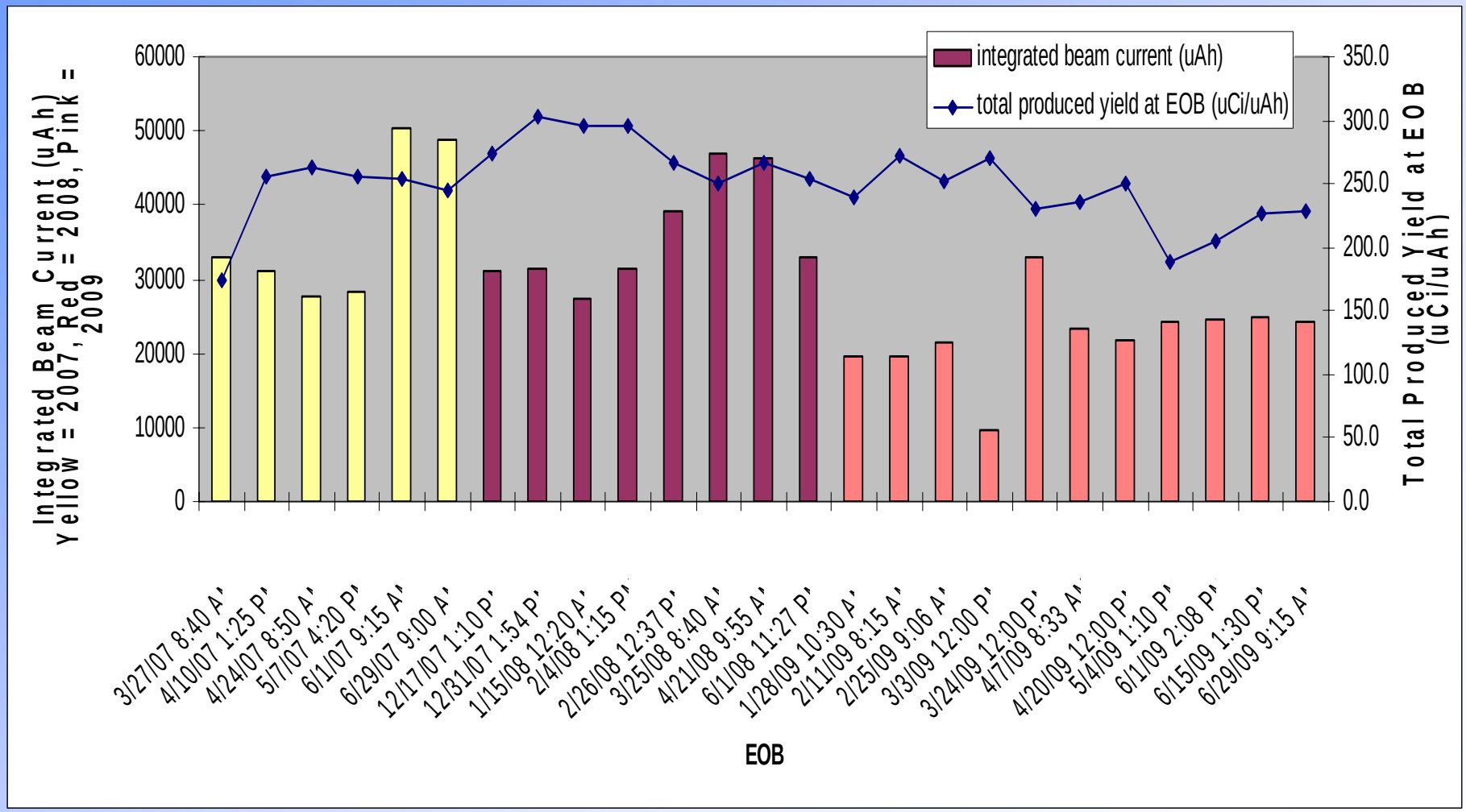


	FY06	FY07	FY08	FY09
Zn-65	48	28	31	67
Fe-55	2500	5000	2500	2502
Ge-68	800	1165	1854	7752
Sr-82	18105	25420	43897	43342
Ni-63 / 10	10700	3000	16086	7562

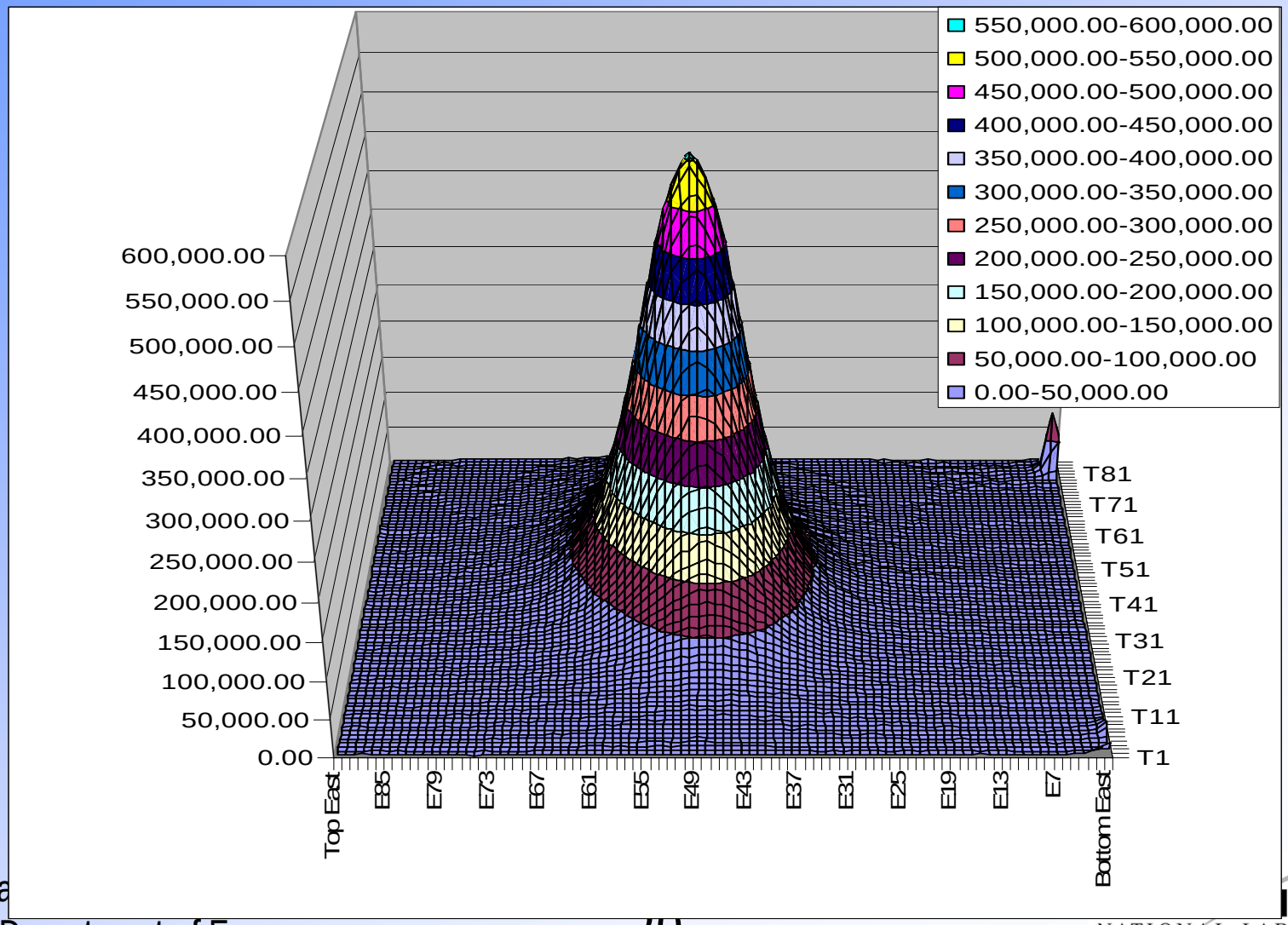
Isotope Shipments



Sr-82 Batch yield trend



Measured BLIP beam profile (x&y in mm, z is intensity, arbitrary scale)



BLIP beam profile

Parameters	2008	2009
Linac rep rate (Hz)	6.67	6.67
DF with PP	0.85#	0.92*
Pulse width@ base (μs)	412	440.0
Pulse height @Max (mA)	37	32
Measured current (μA)	78.6	68
Beam spot FWHM mm	17vx20h	14vx19h
Beam outside target	~8%	0%
Current within target (μA)	72.3	68

*2 pulse every 3.97 sec
#Every 7th pulse

Yield (µCi/µAhr) variation with beam spot size

- An experiment was performed to assess if the smaller beam spot in 2009 effected yield.
- RbCl was irradiated for 24 hr at 19 µA, immediately followed by another RbCl irradiation for 24 hr at 77µA and each assayed for Sr-82.
- Sr-82 EOB yield at 19µA was 19% higher than at 77µA
- We conclude that the higher power density from smaller beam spot caused larger central melt zone in RbCl target. RbCl expands 20% upon melting and thus migrates out of central high temperature zone, refreezing on target periphery. Thus there is less salt within main irradiation zone.
- The proposed solution is to create a more uniform beam intensity profile with octupole magnets. This should lower the peak power density but preserve the integrated intensity.

Facility upgrade projects status

- Replace 60 year old laboratory distilled water system – project complete
- Upgrade hot cell shielding – project complete
- Upgrade BLIP ventilation system for EPA compliance – project complete
- Redesign BLIP target assembly for increased irradiation flexibility – project complete, installation in December
- Replace hot cell acid fume scrubber system – equipment delivered; installation postponed until summer 2010 due to recent construction stand down
- Procure inductively coupled plasma mass spectrometer (ARRA)-unit ordered, delivery & installation in December
- Laser profile monitor to measure beam energy and profile – fabrication nearly complete, installation by late December.
- Fabricate and install new multiwire beam profile chamber in beam line to replace broken unit – fabrication complete, installation in December 2009
- Fabricate and install new vertical steering magnets associated with octupoles – fabrication complete, installation in December 2009
- Modify Low Energy Beam Transport (LEBT) at Linac – installation to be completed by late December, should increase BLIP beam current 15-20%

Non programmatic building construction projects

- HVAC upgrade in 801 to provide more conditioned make up air – demolition complete, project on hold due to accident
- New ventilation ducting and stacks for all fume hoods and hot cells to replace large stack – project construction scheduled ~ March-October 2010
- Remove exterior underground waste pipes and ducts surrounding building – ongoing for several years
- All these efforts can potentially impact or at least inconvenience us

Programmatic risks

- Schedule risk: Length and timing of BLIP operations dependent on RHIC program
  - Mitigated by frequent communication with CAD management (eg. weekly accelerator time meetings), coordination with LANL, and dedicated BLIP operations
- Technical risk: Equipment failure, construction schedule slippage
  - Equipment risk is mitigated by carrying an inventory of spare components for all critical equipment (eg. beamline components, BLIP sensors, pumps, manipulators, control system hardware etc.)
  - Construction risk is mitigated by communication with Facility & Operations staff supervising conventional construction .