Radiation Capabilities at Brookhaven National Laboratory

RaDAITE 2018 Collaboration Meeting

Dohyun Kim

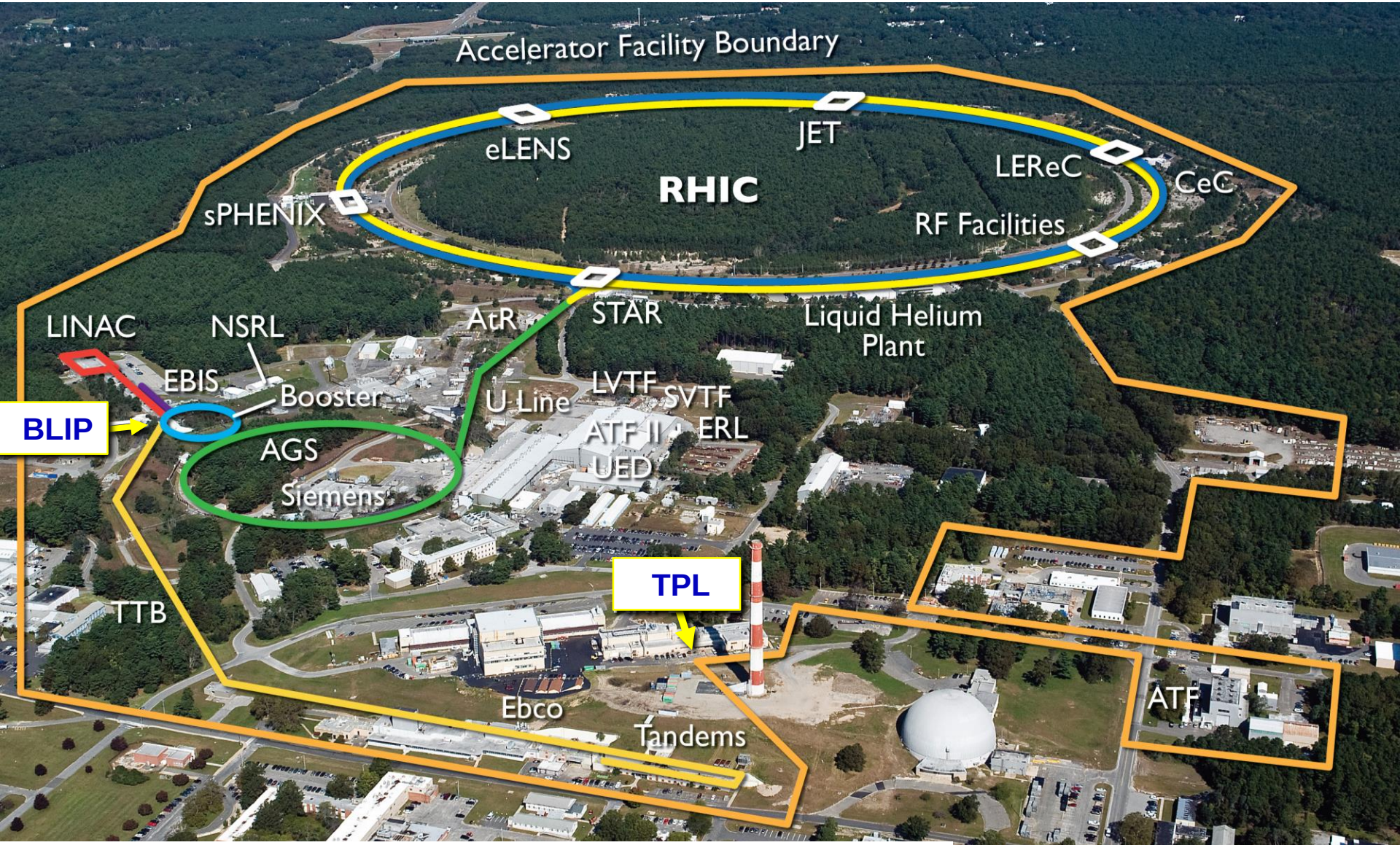
December 18, 2018

BROOKHAVEN NATIONAL LABORATORY

a passion for discovery

U.S. DEPARTMENT OF ENERGY | Office of Science

BNL Isotope Program – Aerial View of Integrated Accelerator Facilities

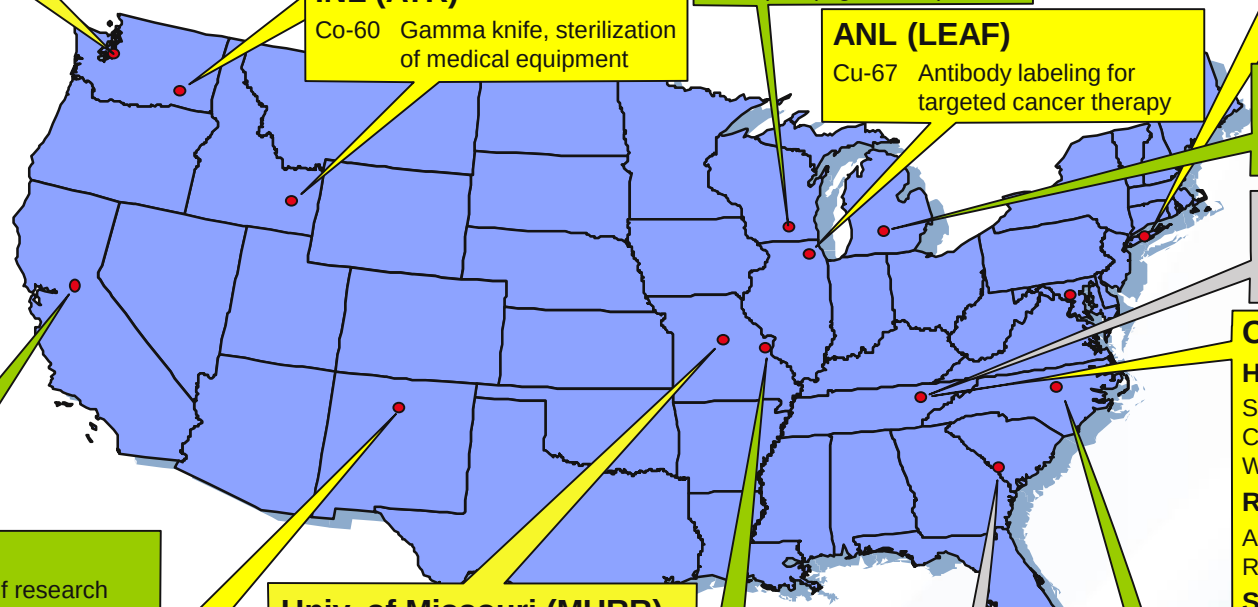


*BLIP = Brookhaven Linac Isotope Producer, **TPL = Target Processing Laboratory

National Isotope Program Mission

- Produce and/or distribute radioactive isotopes that are in short supply, including valuable by-products, surplus materials and related isotope services.
- Maintain the infrastructure required to produce and supply isotope products and related services
- Conduct R&D on new and improved isotope production and processing techniques which can make available new isotopes for research and applications.
  - **Core R&D where there are Programmatically stewarded activities**
  - **Competitive R&D**
  - **SBIR/STTR, Early Career Award Program,**
  - **Nuclear and Radiochemistry Summer School, Workforce Development**

DOE Isotope Program Production and/or Development Sites



Univ. of Washington
Supplier of research isotopes (e.g., At-211)

PNNL
Sr-90 Y-90 generator for cancer therapy
Ra-223 Cancer therapy
Np-237 Research

INL (ATR)
Co-60 Gamma knife, sterilization of medical equipment

Univ. of Wisconsin
Development of research isotopes (e.g., Cu-64)

ANL (LEAF)
Cu-67 Antibody labeling for targeted cancer therapy

BNL (BLIP)
Ge-68 Ga-68 generator for tumor imaging
Sr-82 Rb-82 generator for cardiac imaging
Cu-67 Antibody labeling for targeted cancer therapy

Michigan State Univ. (FRIB)
Development of isotope harvesting (e.g., Mg-28, Si-32, Ca-47)

Y-12 (NNSA Facility)
Li-6 Neutron detection
Li-7 Radiation dosimeters

ORNL
HFIR:
Se-75 Industrial NDA
Cf-252 Industrial sources
W-188 Cancer therapy
Radioisotopes Inventory:
Ac-225 Cancer therapy
Ra-223 Cancer therapy
Stable Isotopes Inventory:
E.g., Ca-48, Ga-69, Rb-87, Cl-37
Stable Isotope Production

UC Davis
Development of research isotopes (e.g., At-211, Zr-89, Y-86, Pb-203)

Univ. of Missouri (MURR)
Supplier of research isotopes (e.g., Se-75, Lu-177)

LANL (IPF)
Ge-68 Ga-68 generator for tumor imaging
Sr-82 Rb-82 generator for cardiac imaging
As-73 Environmental tracer
Si-32 Oceanographic research

Washington Univ.
Development of research isotopes (e.g., Cu-64)

Duke University
Development of research isotopes (e.g., At-211)

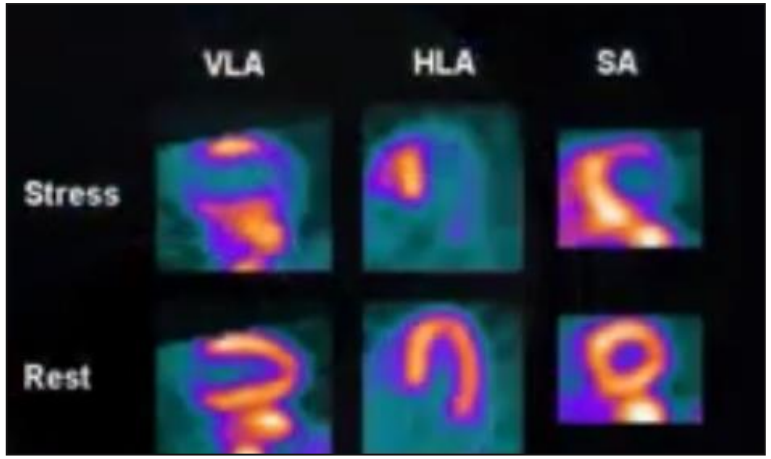
SRNL (NNSA Tritium Facility)
He-3 Neutron detection
Fuel source for fusion reactors
Lung testing

BROOKHAVEN NATIONAL LABORATORY

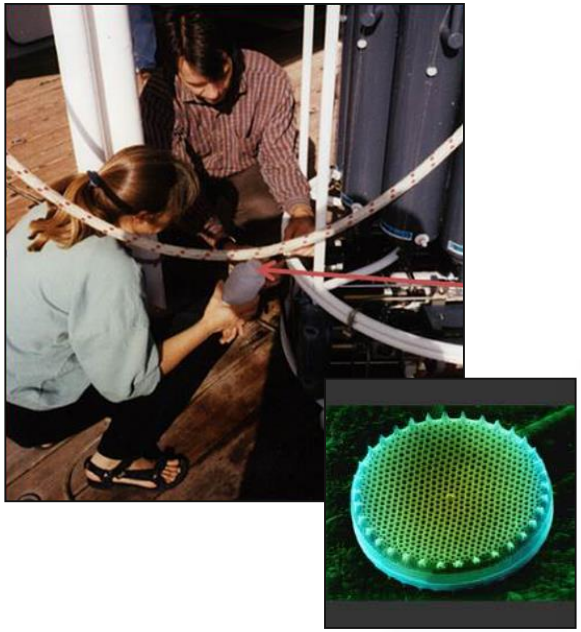
BNL Products, Services and Applications that Serve a Multiplicity of National and Commercial Programs in the United States

Applications – Accelerator Isotopes

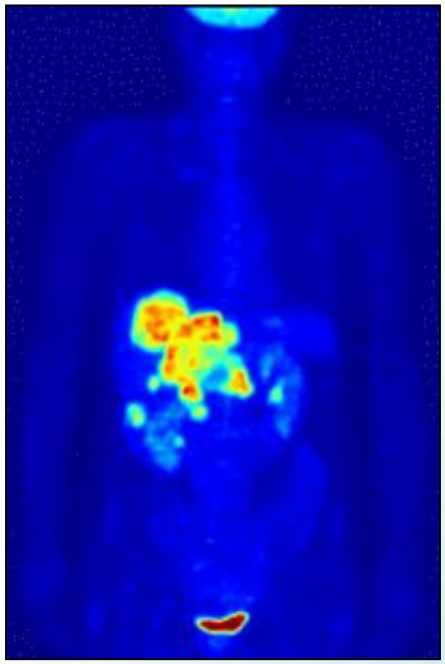
Sr-82/Rb-82:
Generator- cardiac imaging



Si-32: Environmental applications



Ge-68/Ga-68:
Generator-
cancer imaging



Na-22: Source for PET imaging

Cd-109: X-ray fluorescence source

Brookhaven Linac Isotope Producer (BLIP)

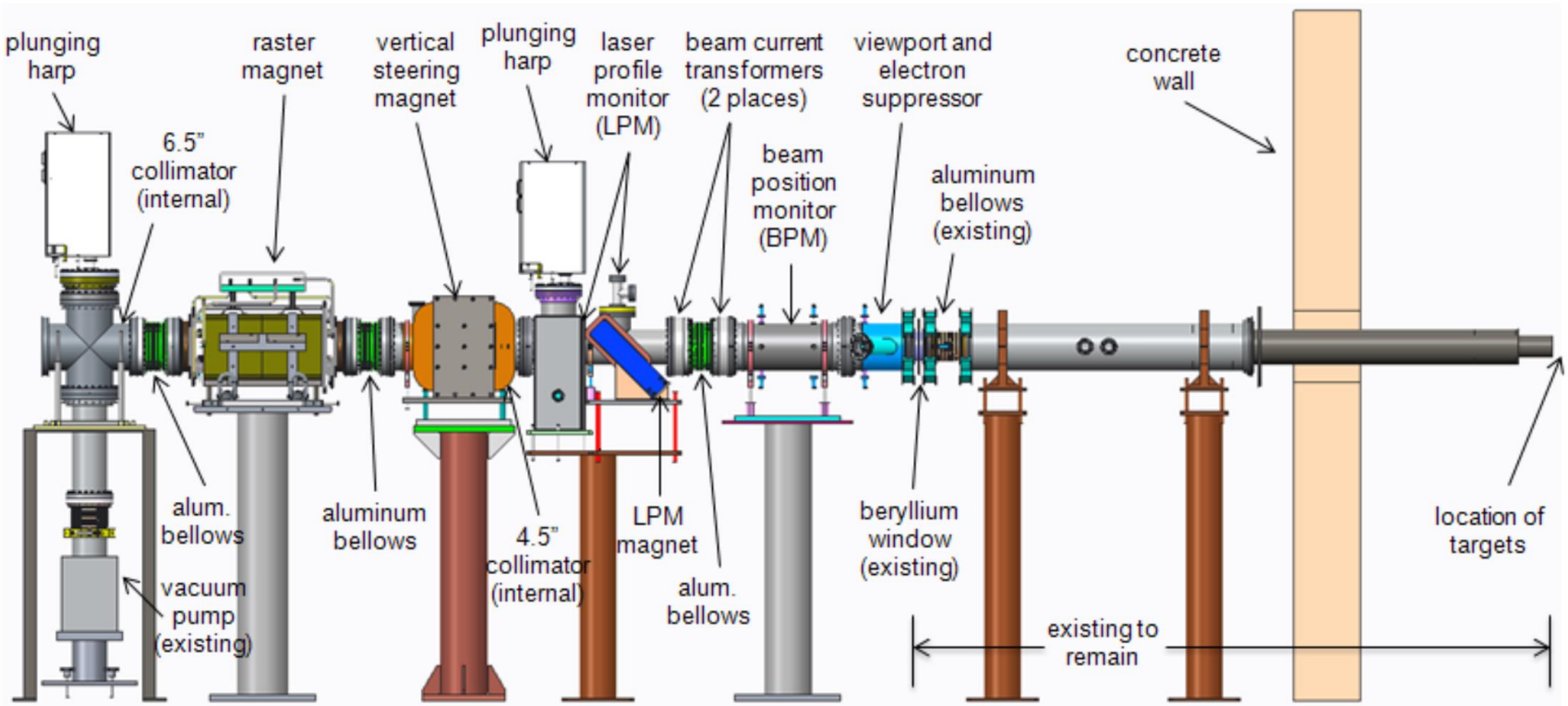


FIGURE 2: New BLIP beam-line layout. Length from vacuum pump center to beryllium window flange is 141.18".

The New BLIP Raster System and Associated Target Modifications

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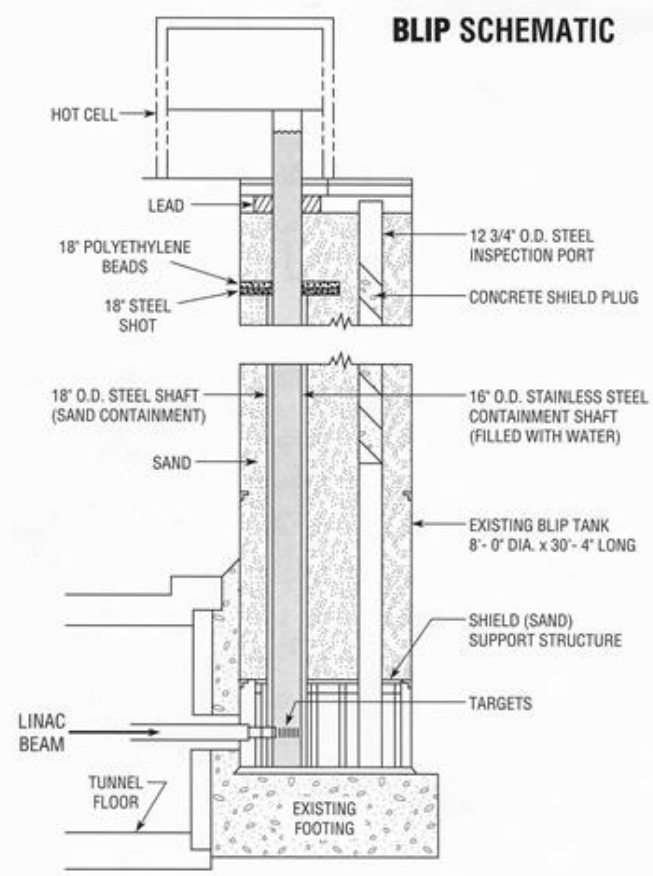
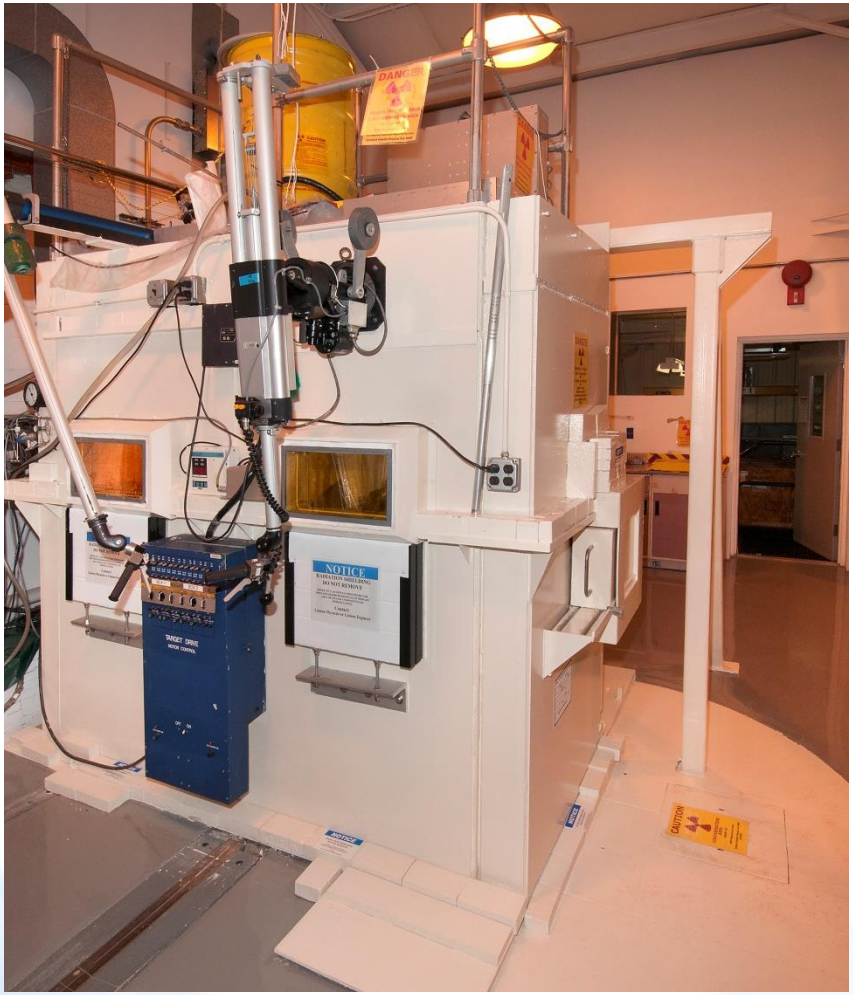
Brookhaven Linac Isotope Producer (BLIP)

- First to use a high energy proton accelerator to produce isotopes (1972)
- BLIP utilizes the beam from the 200-MeV Linac that injects the Booster, which leads to AGS and RHIC accelerators (nuclear physics)
- Excess Booster pulses (~90%) are diverted to BLIP. Energy is incrementally variable from 66-202 MeV
- The BLIP beam line is synergistic operation with nuclear physics programs for more cost effective isotope production
- In 2016, implemented beam rastering and increasing (increased) linac current to increase isotope production capabilities

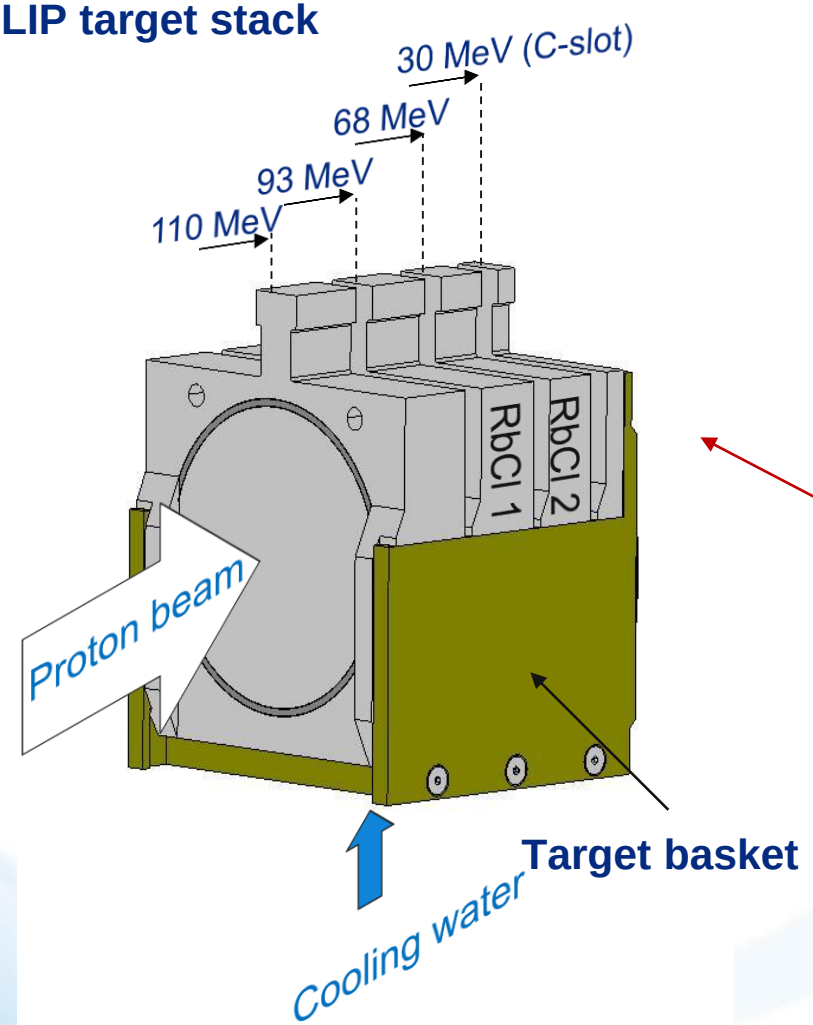


BLIP Hot Cell

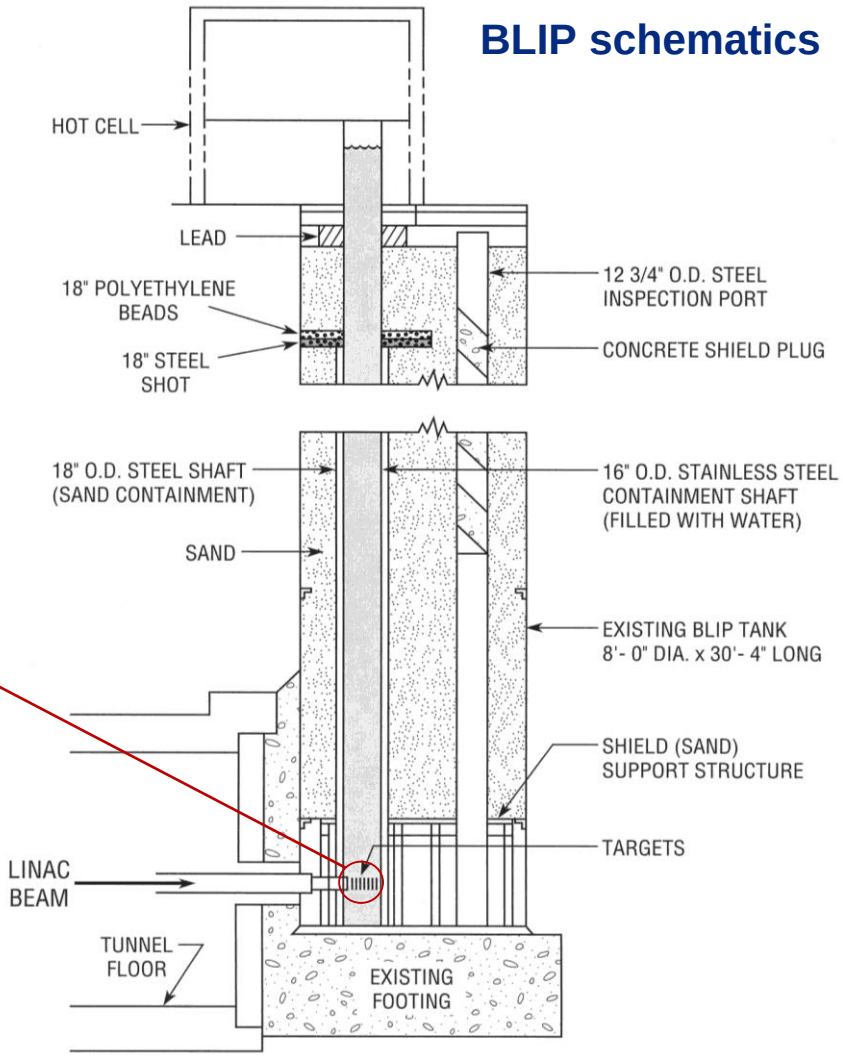


BLIP Target

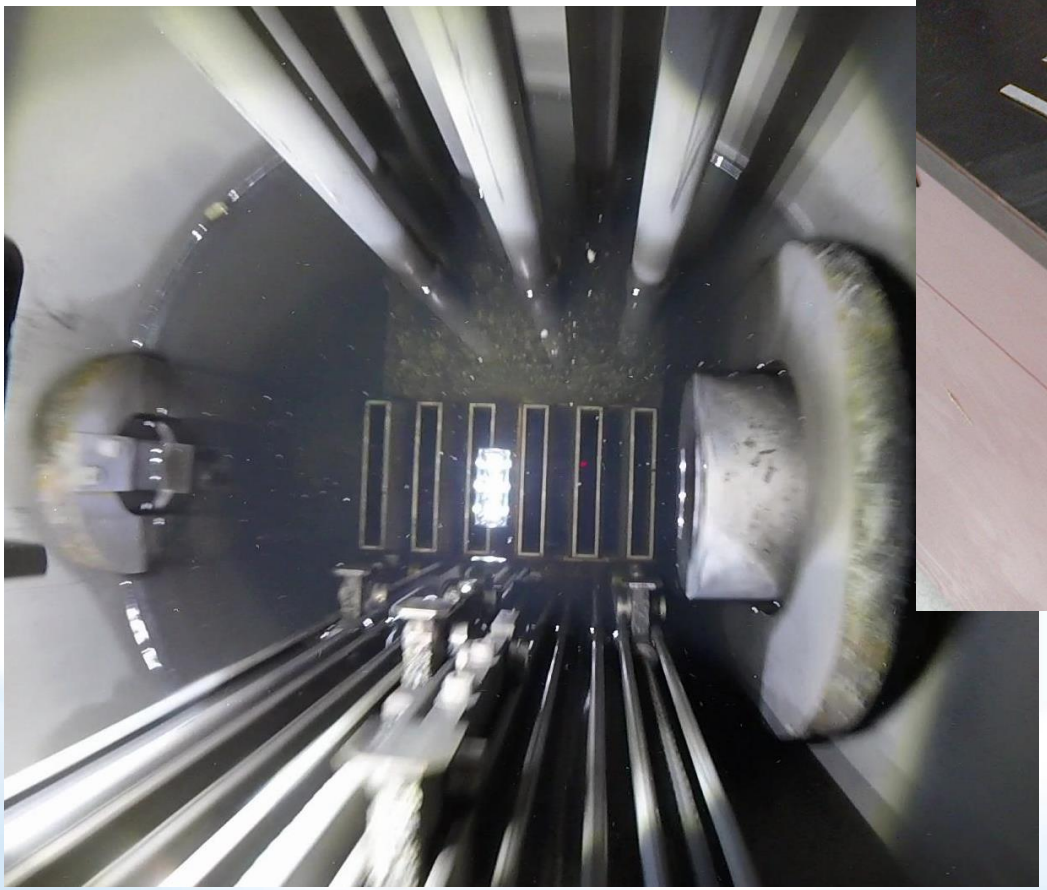
BLIP target stack

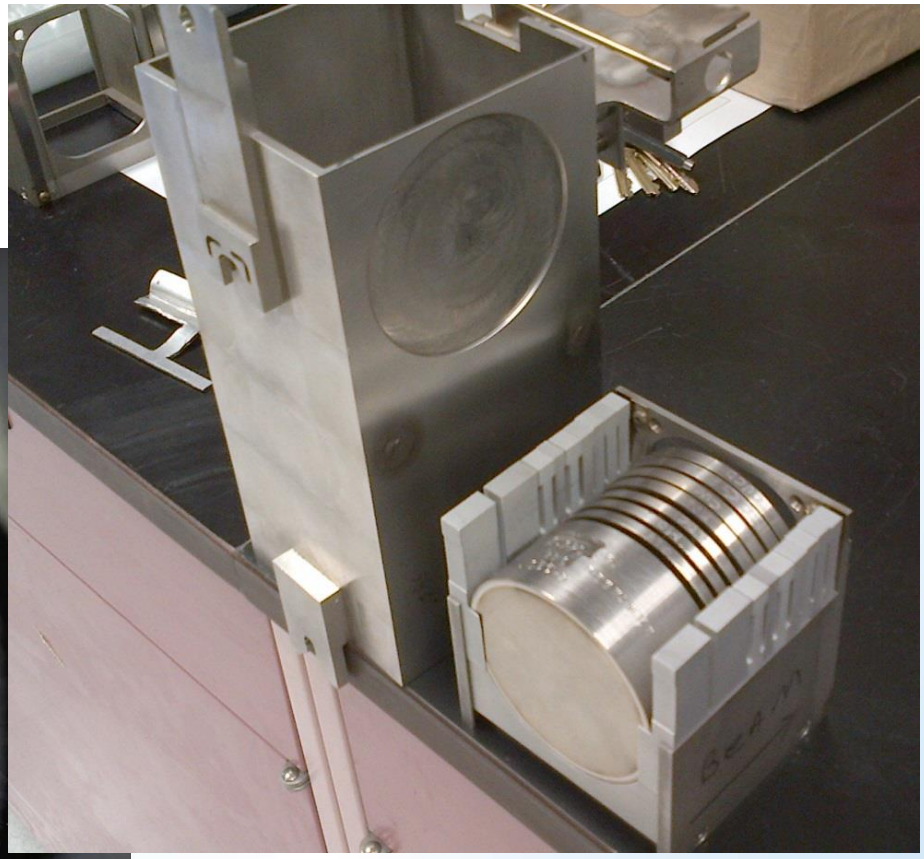


BLIP schematics



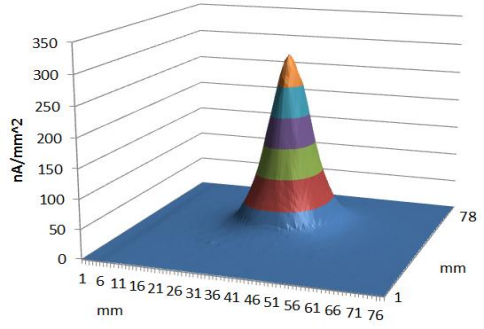
Target Box & Cooling

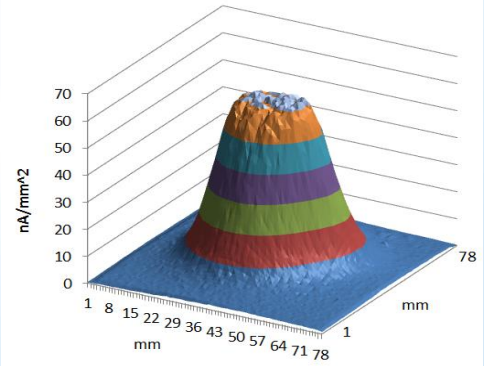




Next, BNL…

- Like LANL, BNL underwent an **Accelerator Improvement Project** (AIP)
  - Phase 1 complete: Current improved to 165 uA in 2016
  - Phase 2 pending: Increase current to 250 uA
    - SAD mod covers up to 300 uA
- **BLIP Raster Project:** Designed, fabricated, installed, and commissioned a BLIP raster system with required beam diagnostics
  - By spreading out the power density, a raster scanning system was installed which was beneficial for all targets by improving reliability and yield
  - A 50% overall increase in Sr-82 yields was achieved.





Raster Beam Pattern

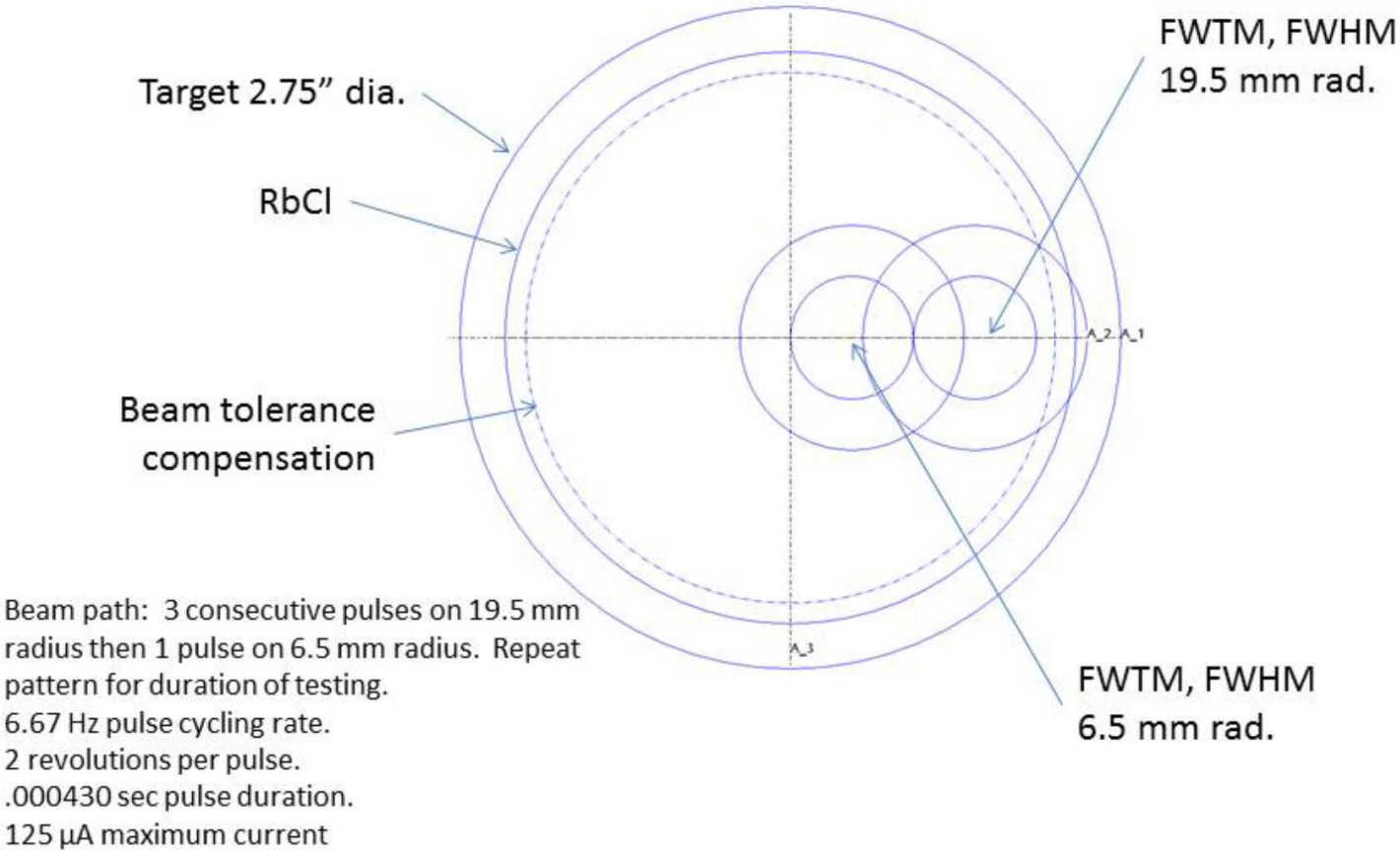
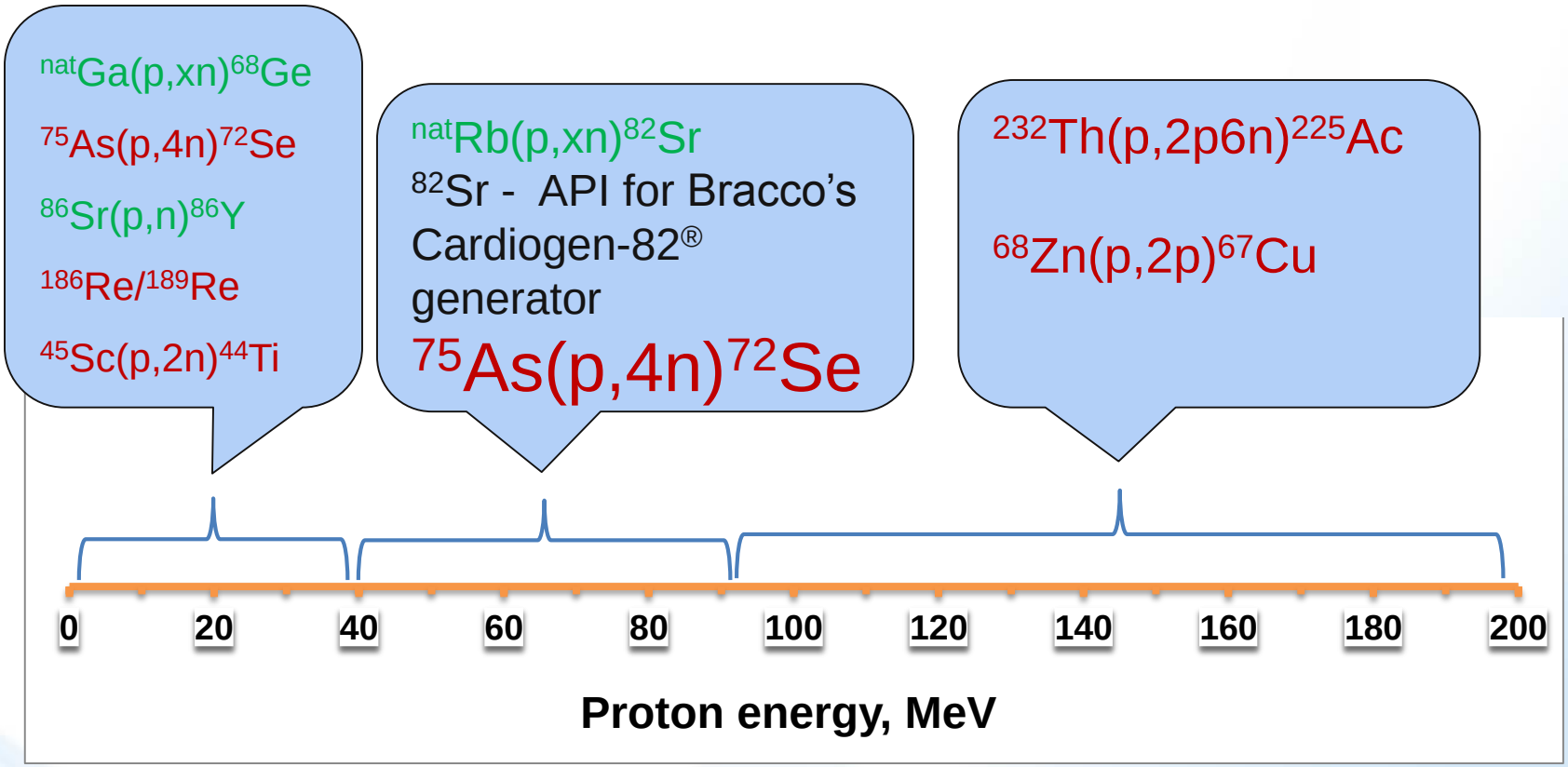


FIGURE 1. Diagram of initially planned circular raster pattern on target.

Opportunities for isotope production and R&D at BLIP



BLIP Facility Improvements

Item	Cost ($)	Risk	Justification	Year	Ops or New $
Linac Quadrapole power supply prototypes	*281K*	*Med*	*Eliminate the technical risk and reduce the cost of the Phase II Intensity Upgrade*	*2017-2019*	*In progress*
Blip cooling and target drive system upgrade	$1.2 M	Med	Accept higher currents, resulting in higher isotope yields and more sustainable operations	2018 14 months to complete	New
Vacuum Upgrade	661K	Med	Change components to off the shelf items, changes to lower dose to personnel	2018	New
Linac Intensity Upgrade Phase II	9.8M	Med-SPF	Increase isotope yields and allow more research irradiations without scarificing commercial production	2020 with planning in 2018-19	New
Reduce air emissions	655K	Med	Add delay line	2019	New

BNL Post-Irradiation Facilities

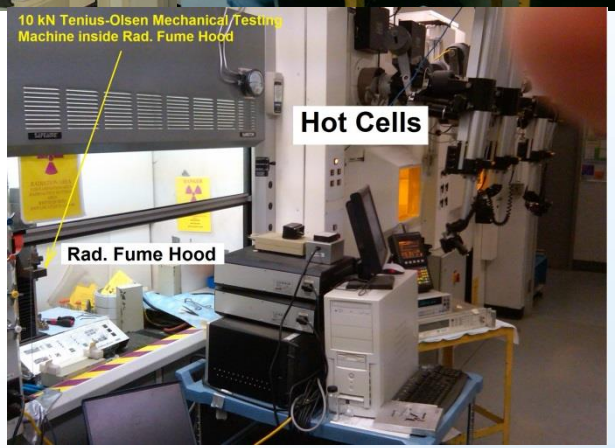
Isotope Extraction and Processing Facility at BNL

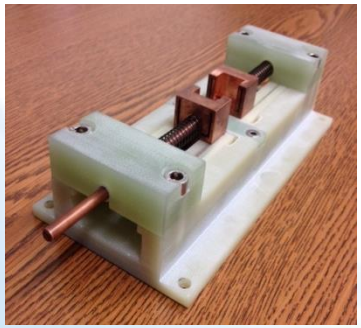
Experimental Facility occupies 2 hot cells and a HEPA-filtered fume hood

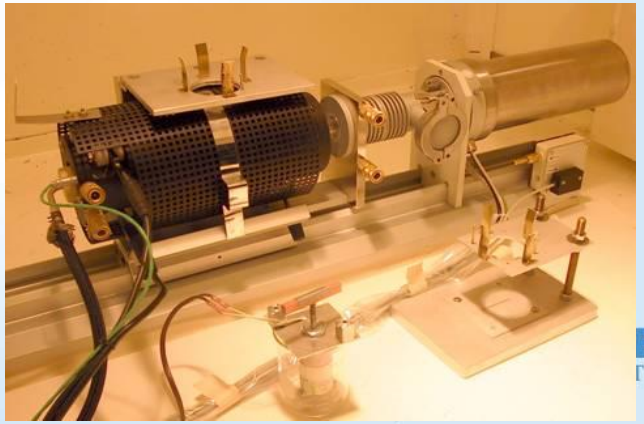
PIE analyses performed are:

Stress-strain (tension, 3-point and 4-point bending)
Thermal Expansion and annealing (extremely sensitive dilatometer)
Thermal Conductivity (electrical resistivity)
Magnetic Whole probe
Ultrasonic measurements

PLUS
Photon spectra and isotopic analysis
Activity measurements
Weight loss or gain







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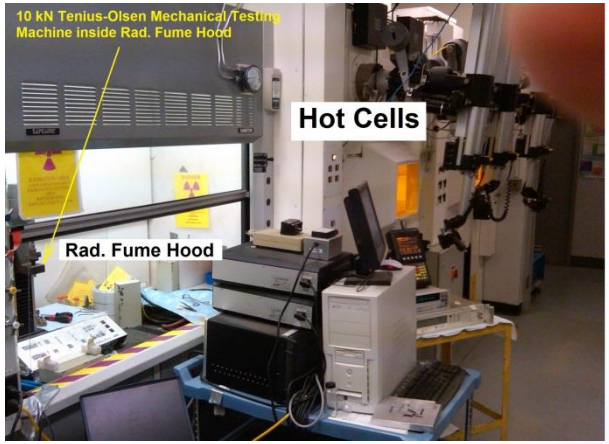
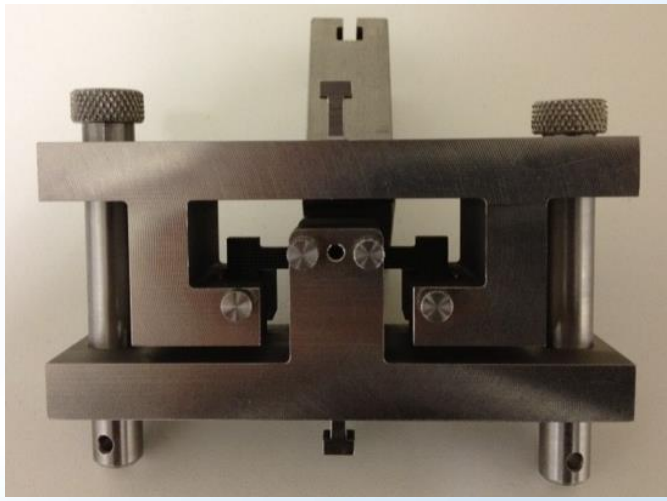




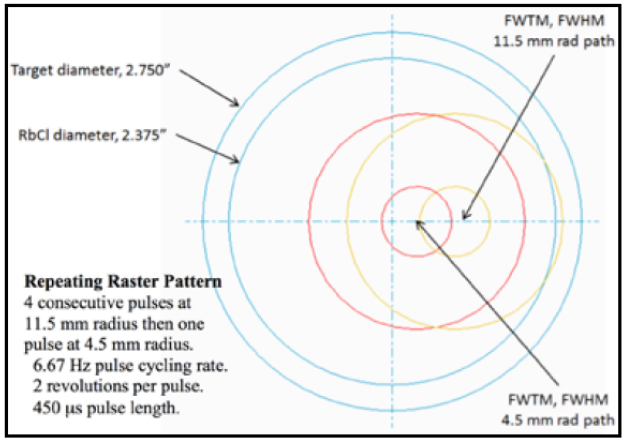


Figure 3: Diagram of beam images on target plotted at the right most positions for each radius of the circular raster pattern used during 117 MeV ^{82}Sr production from January 2016 to March 22, 2016. On March 22, 2016 the 117 MeV beam size was reduced from 13 mm FWHM and 40 mm FWTM to 10 mm FWHM and 23 mm FWTM, and the raster pattern was changed to the repeating pattern of 4 beam pulses at 12.5 mm radius and 1 beam pulse at 5.5 mm radius.

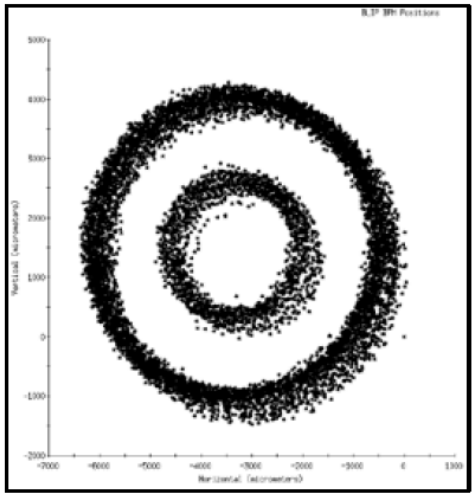
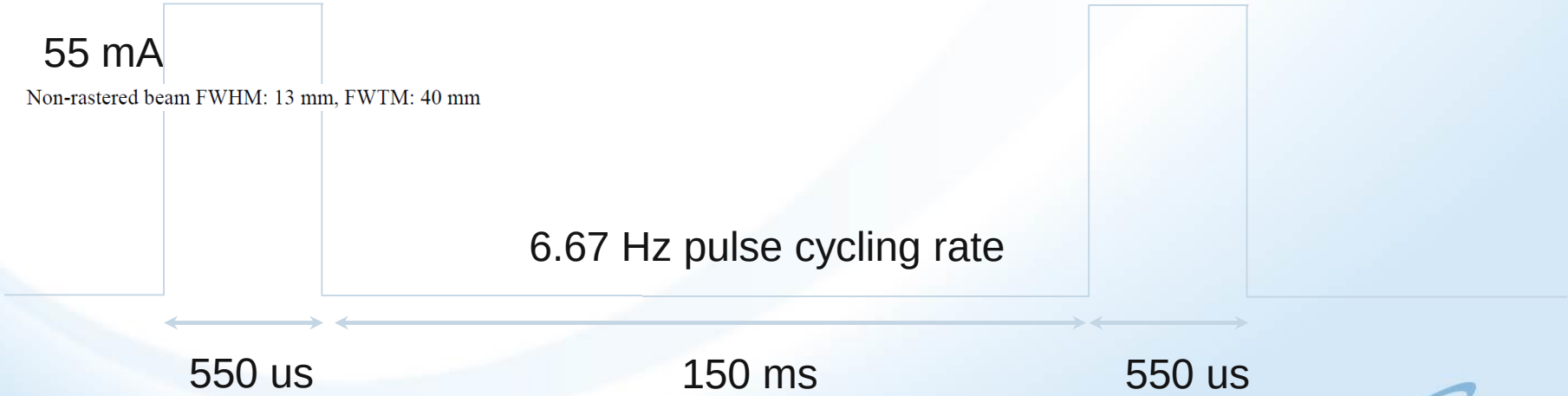
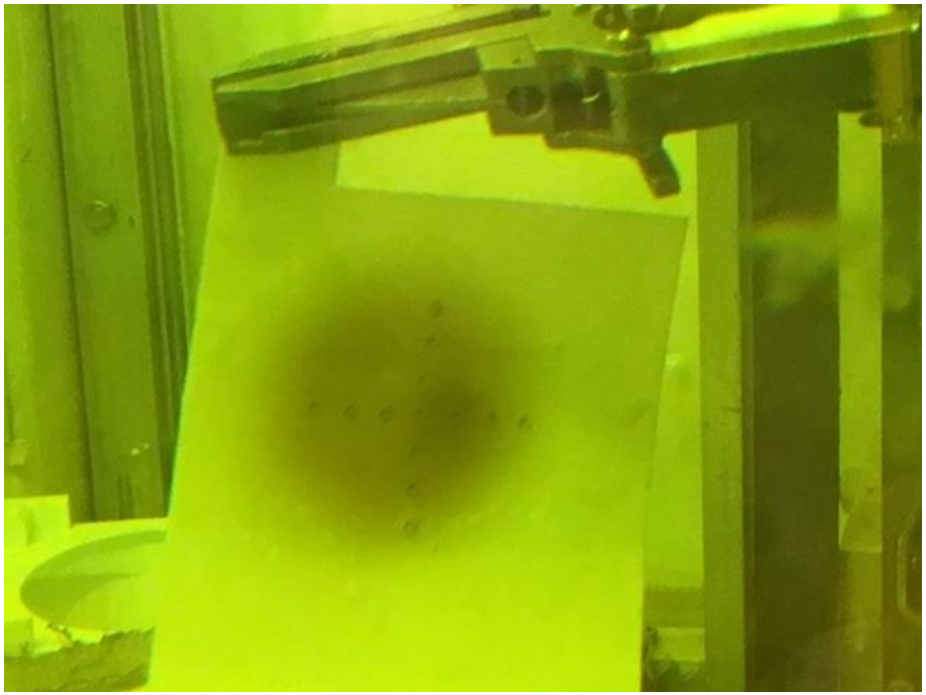
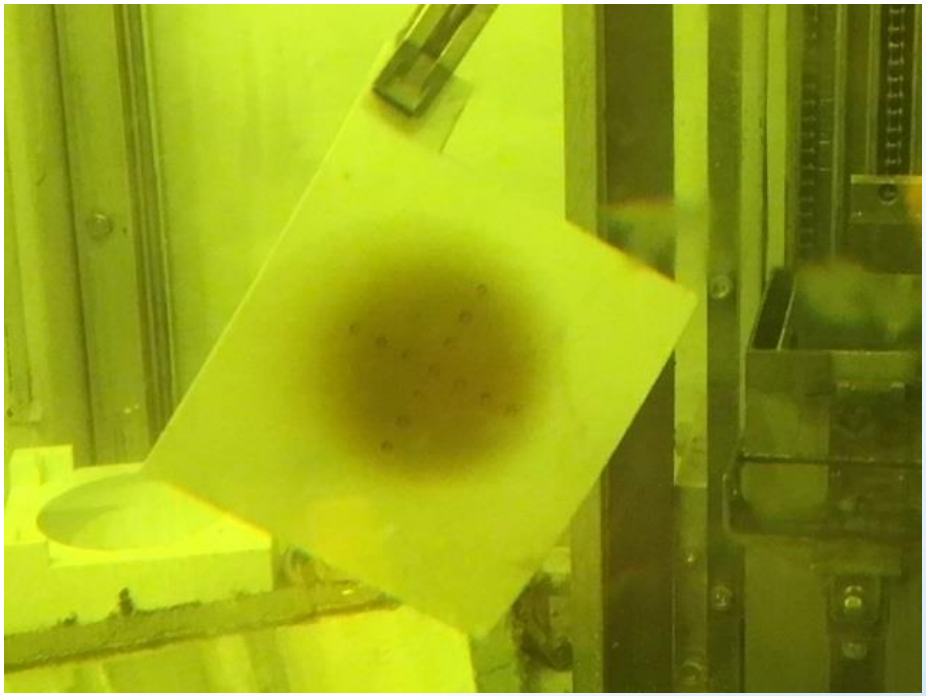


Figure 5: Beam position monitor data [3], horizontal vs. vertical (~100 points per beam pulse), March 30, 2016, 117 MeV beam and repeating raster pattern radii of 12.5 mm and 5.5 mm at the target. The actual positions at the BPM are about 1.8 times that shown in the plots.







Questions