# Recent Radioisotope Developments at BNL

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BROOKHAVEN NATIONAL LABORATORY

# Radionuclide and Radiopharmaceutical Research (R&RR) Program at BNL

- **Radionuclide R&D**
  - New/unique radionuclides
  - Nuclear reactions, targetry
  - Processing chemistry, generator development
- **Radiopharmaceutical R&D**
  - Recombinant vehicles for targeting tumors with diagnostic/therapeutic isotopes with rigid bifunctional chelating agents
  - Tin-117m chelates: bone pain and bone cancer therapy
  - Radiolabeled stem cells for non invasive imaging
- **Isotope Production and Distribution**
  - Distribution of BLIP-produced isotopes
  - Process development research: improve quality and speed, minimize waste and/or personnel exposure.

# Major Equipment and Facilities at BNL

## Dedicated

-Brookhaven Linac Isotope Producer (BLIP)

-Hot Laboratory Facilities

-High Level Radiation Processing Cells

-Radiochemistry Laboratories

-Analytical Instruments and Counting Equipment

## Shared Use

-200 MeV Proton Linac

-Chemistry Cyclotrons

-Center for Imaging and Neurosciences (SPECT, PET, and MRI)

-Laboratory Animal Facilities

-Clinical Research Center

-Patients from various area institutions including SUNY, Stony Brook

## Ancillary Support

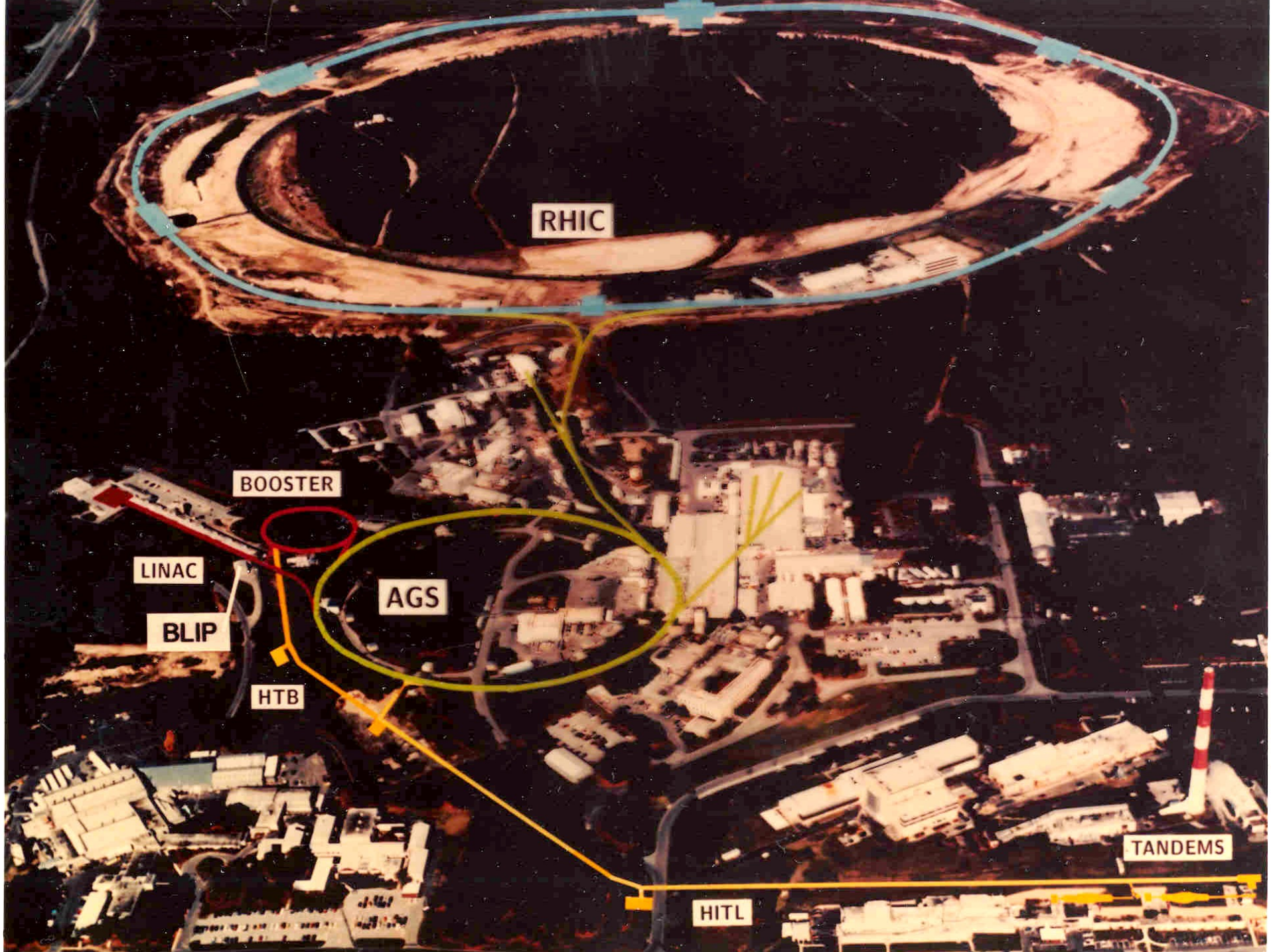
-Instrumentation, Machine Shops

-Accelerator and Magnet Design; Engineering Support

-State-of-the-Art Analytical Equipment and Services

-Computational Facilities

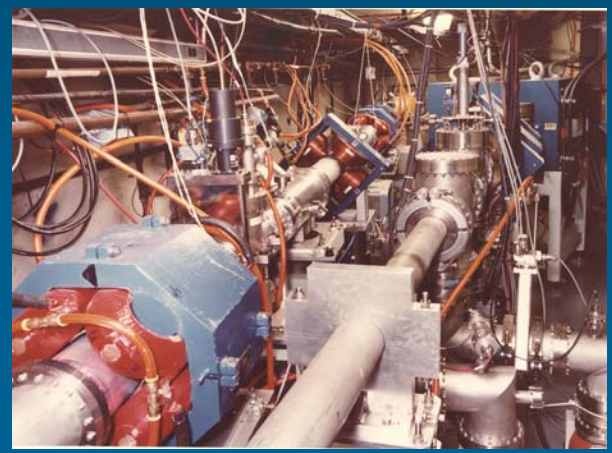
-Waste Management

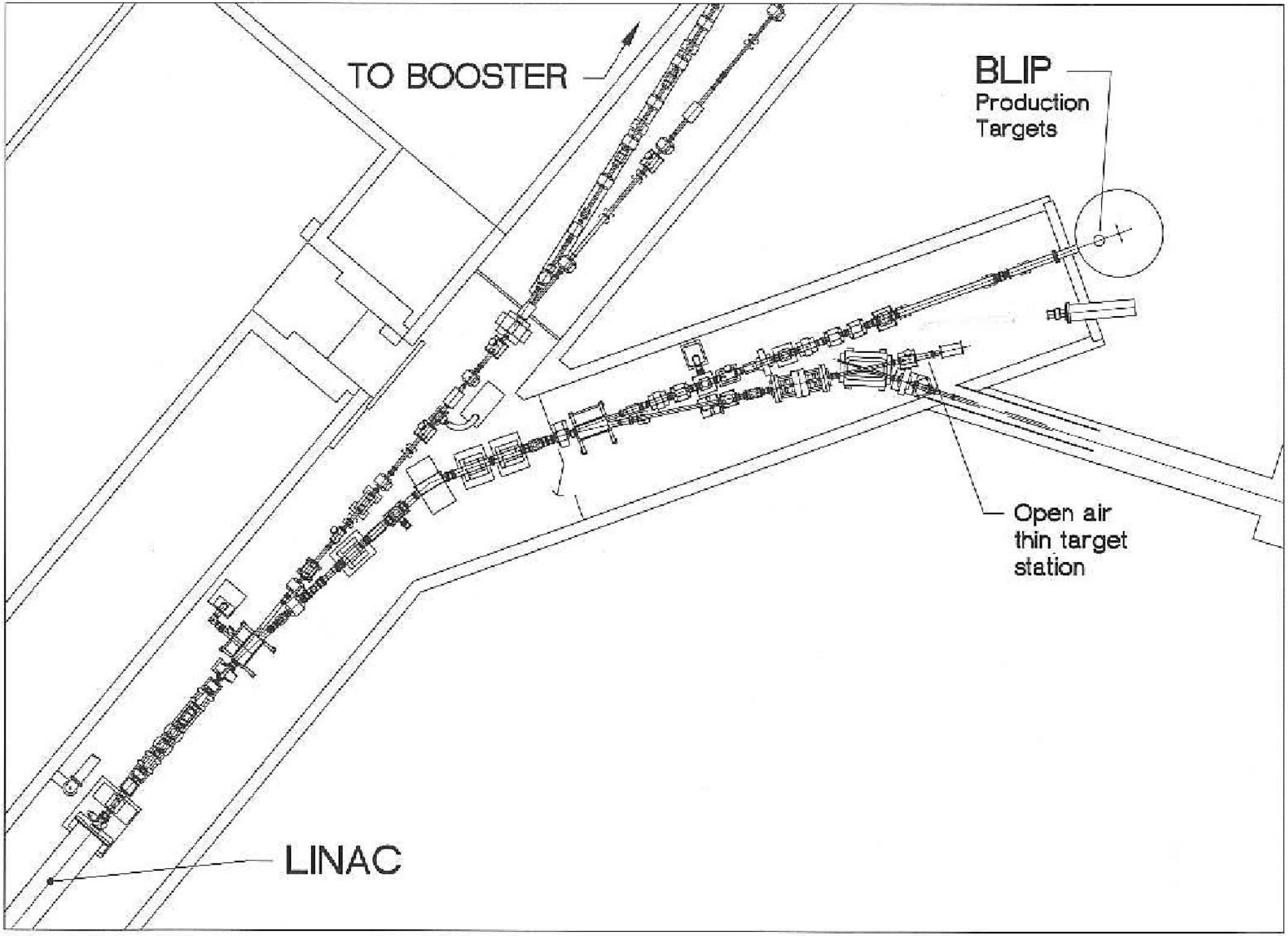

RHIC
BOOSTER
LINAC
AGS
BLIP
HTB
TANDEMS
HITL

# Brookhaven LINAC Isotope Producer (BLIP)

The high energy proton LINAC injects beam into Booster for further acceleration for high energy physics research and into BLIP for isotope production.

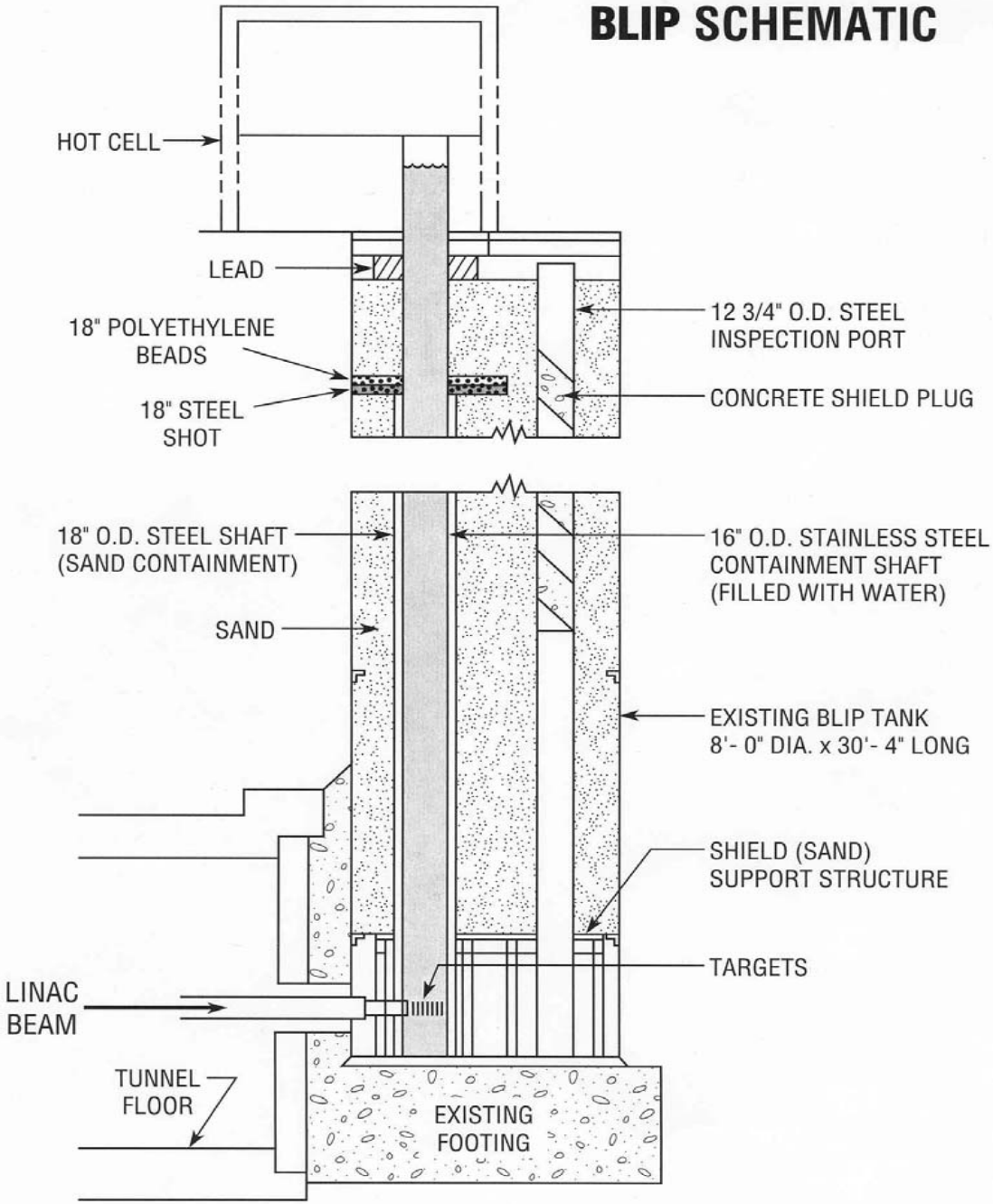
BLIP beam line directs protons to isotope production targets at beam intensity up to 115□A . Energy is variable stepwise ranging from 66 to 200 MeV. Beam is available from 10-22 weeks per year, dependent on physics funding.






Schematic of BLIP Beam Line

# BLIP SCHEMATIC



# Target Processing Laboratory (TPL)

- All isotope production targets require some chemical processing
- Nine hot cells with steel clad lead walls (15.25cm thick) are used for remote handling and target processing

# Radioisotopes Produced at BNL - I

| Isotope | Half-life | Decay mode | Nuclear reaction | Typical application |
|---|---|---|---|---|
| $^{7}$Be | 53.3d | EC | $^{12}$C(p,spall) | ☎ source |
| $^{28}$Mg | 21h | $\beta^-$ | Cl(p,spall) | Mg tracer |
| $^{22}$Na | 2.6y | $\beta^+$ | Al(p,spall) | ☎ source |
| $^{47}$Sc | 3.4d | $\beta^-$ | $^{48}$Ti(p,2p) | Radioimmuno-therapy (RIT) |
| $^{52}$Fe | 8.3h | $\beta^+$(57%),EC | Ni(p,spall) | PET tracer, Fe metabolism |
| $^{55}$Co | 17.5h | $\beta^+$(81%),EC | $^{56}$Fe(p,2n) | PET label; RIT |
| $^{64}$Cu | 12.7 h | | | PET label; RIT |
| $^{65}$Zn | 244d | EC | $^{69}$Ge(p,✂n) | Zn tracer |
| $^{67}$Cu | 61.9h | $\beta^-$ | $^{68}$Zn(p,2p) | RIT |
| $^{68}$Ge/$^{68}$Ga | 271d/68m | EC | $^{nat}$Ga(p,2n/4n) | PET calibration |
| $^{73}$As | 80.3d | EC | $^{74}$Ge(p,2n) | As tracer |
| $^{81}$Rb/$^{81m}$Kr | 4.6h/13s | EC/IT | $^{nat}$Kr(p,4n) | Lung ventilation |

HFBR-produced

# Radioisotopes Produced at BNL - II

| Isotope | Half-life | Decay mode | Nuclear reaction | Typical application |
|---|---|---|---|---|
| $^{82}$Sr/$^{82}$Rb | 25.4d/75s | EC/$\beta^+$ | $^{nat}$Rb(p,4n/6n) | PET studies of heart |
| $^{88}$Y | 106.6d | EC | Mo(p,spall) | Y tracer |
| $^{95m}$Tc | 61d | EC | $^{103}$Rh(p,spall) | Tc tracer |
| $^{96}$Tc | 4.3d | EC | $^{103}$Rh(p,3p5n) | Tc Tracer |
| $^{97}$Ru | 2.89d | EC | $^{103}$Rh(p,2p5n) | SPECT label |
| $^{109}$Cd | 461.4d | EC | $^{109}$Ag(p,n) | ☎ source |
| $^{117m}$Sn | 13.6d | IT | $^{117}$Sn(n,n'☎) | Bone pain palliation |
| $^{122}$Xe/$^{122}$I | 20.1h/3.6m | EC/$\beta^+$ | $^{133}$Cs(p,spall) | $^{122}$I generator |
| $^{124}$I | 4.2 d | $\beta^+$ | | PET tracer |
| $^{127}$Xe | 36.4d | EC | $^{133}$Cs(p,2p5n) | Lung/brain imaging |
| $^{153}$Sm | 1.9 d | $\beta^-$ | $^{152}$Sm(n,☎) | Bone pain palliation |
| $^{195m}$Pt | 4.0 d | IT | 192Os(✂,2n) | Rx Aug. emitter |
| $^{203}$Pb | 51.9h | EC | $^{209}$Bi(p,2p5n) | RIT |

HFBR-produced

# Radioisotopes Distributed from BNL

| Isotope | Half- life | Typical application |
|---|---|---|
| $^{7}$Be | 53.3d | Gamma source |
| $^{22}$Na | 2.61y | Long lived positron source |
| $^{28}$Mg | 21h | Mg tracer |
| $^{73}$As | 80.3d | As tracer |
| $^{65}$Zn | 244.1d | Zn tracer |
| $^{67}$Cu | 61.9h | Radioimmunotherapy |
| $^{68}$Ge/$^{68}$Ga | 271d/68m | PET calibration |
| $^{82}$Sr/$^{82}$Rb | 25.4d/75s | PET studies of heart |
| $^{88}$Y | 106.6d | Gamma calibration source |
| $^{95m}$Tc | 61d | Tc tracer |
| $^{96}$Tc | 4.3d | Tc Tracer |

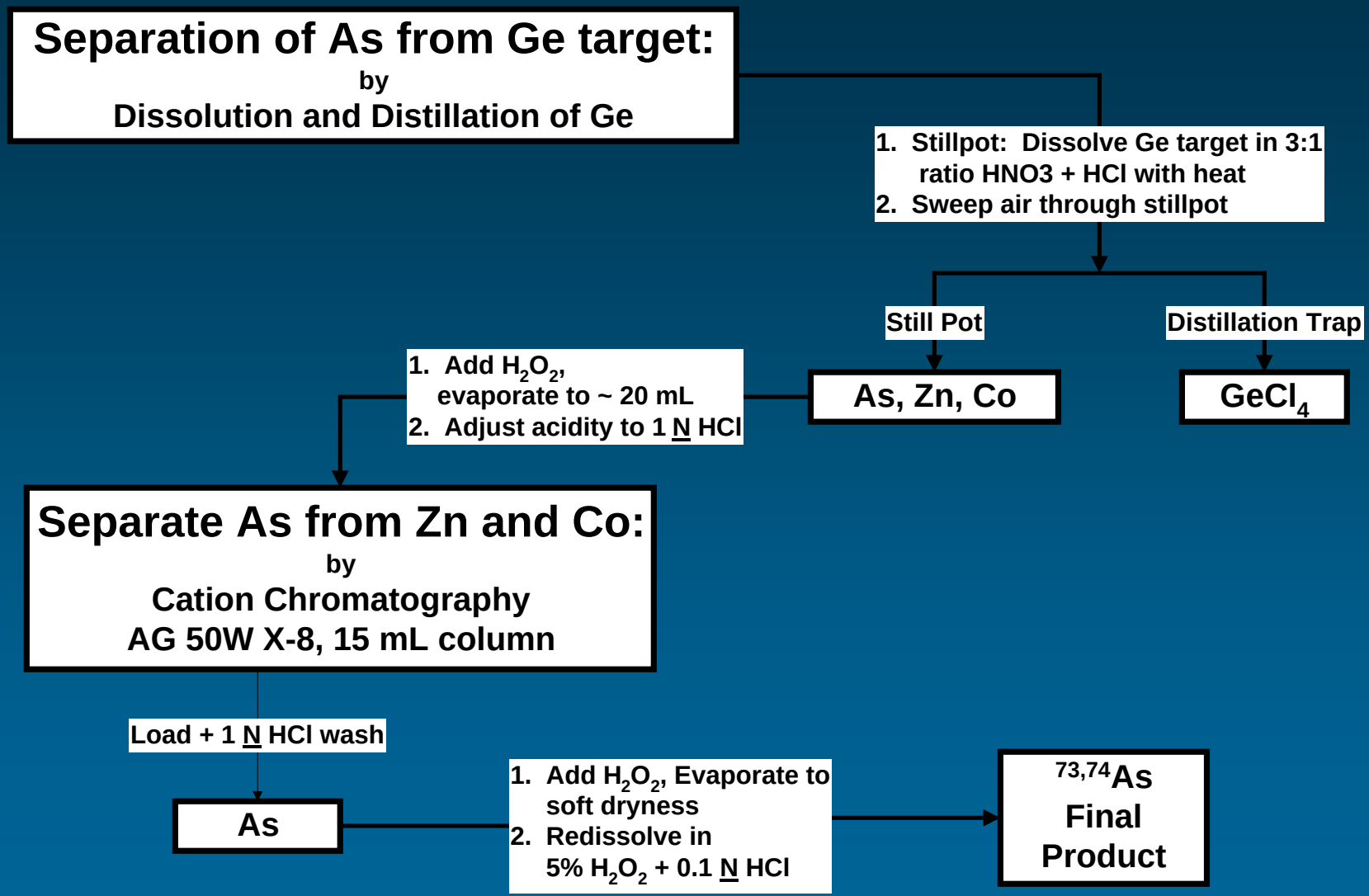
# Development of As-73

- Half life = 80.3 day
- Emissions; gamma ray of 53.4 KeV (10.0%) and 9.86 KeV x-ray (90.5)
- Used as a longer lived substitute for the positron emitter $^{72}As$ (half life 26.0h) during radiopharmaceutical development or as a tracer in environmental studies of arsenic
- Produced by the $^{nat}Ge(p,xn)^{73}As$ nuclear reaction

# Method-Irradiation

- A high purity Ge metal disk 0.508cm by 6.34cm diameter was irradiated at approximately 71 MeV at the BLIP facility
- The irradiation continued for 7 days followed by 11 days of decay and was restarted for another 4 days
- The total beam current was 13,306μAh
- The energy loss in the target was 17.7 MeV

# $^{73}$As Recovery from Proton Irradiated Germanium Targets



# Results

- The irradiation produced 6.0GBq of $^{73}$As and 7.5GBq of $^{74}$As ($t_{1/2}$=17.7d) at EOB.
- Other major isotopic impurities produced were Zn-65, Ge-68, Ge-69, Co-57,58,60
- The overall chemical recovery was 61%
- Non As radioimpurities were reduced to <0.005% after processing
- No As carrier was measured at the 10ppb limit of detection. Theoretical $^{73}$As specific activity is 825MBq/µg

# Discussion

- The nuclear irradiation was not optimized. In addition to to the interrupted bombardment, the incident proton energy of 71 MeV was well above the peak of the nuclear reaction cross section (~25 MeV). A lower energy slot was not available at the time. The coproduction of shorter lived $^{74}$As (17.8d) actually improves the tracer utility of this material due to its higher energy gamma rays (595 KeV)

# Discussion

- The chemical process was also not optimum. The dissolution and distillation step took too long, approximately two weeks. The relatively low chemical recovery of As was due to losses during distillation. We believe this was caused by insufficient addition frequency of peroxide during the long distillation, leading to intermittently inadequate oxidizing conditions to maintain arsenic in the highest oxidation state. It is volatile in the lower +3 state.

# Conclusions

- A lower beam energy will improve nuclear yield
- A target configuration with more surface area should speed up dissolution
- More careful control of the rate of $H_2O_2$ addition during distillation should increase chemical recovery
- Nevertheless, a useful quantity of carrier free $^{73}As$ was produced and this material has been made available to researchers

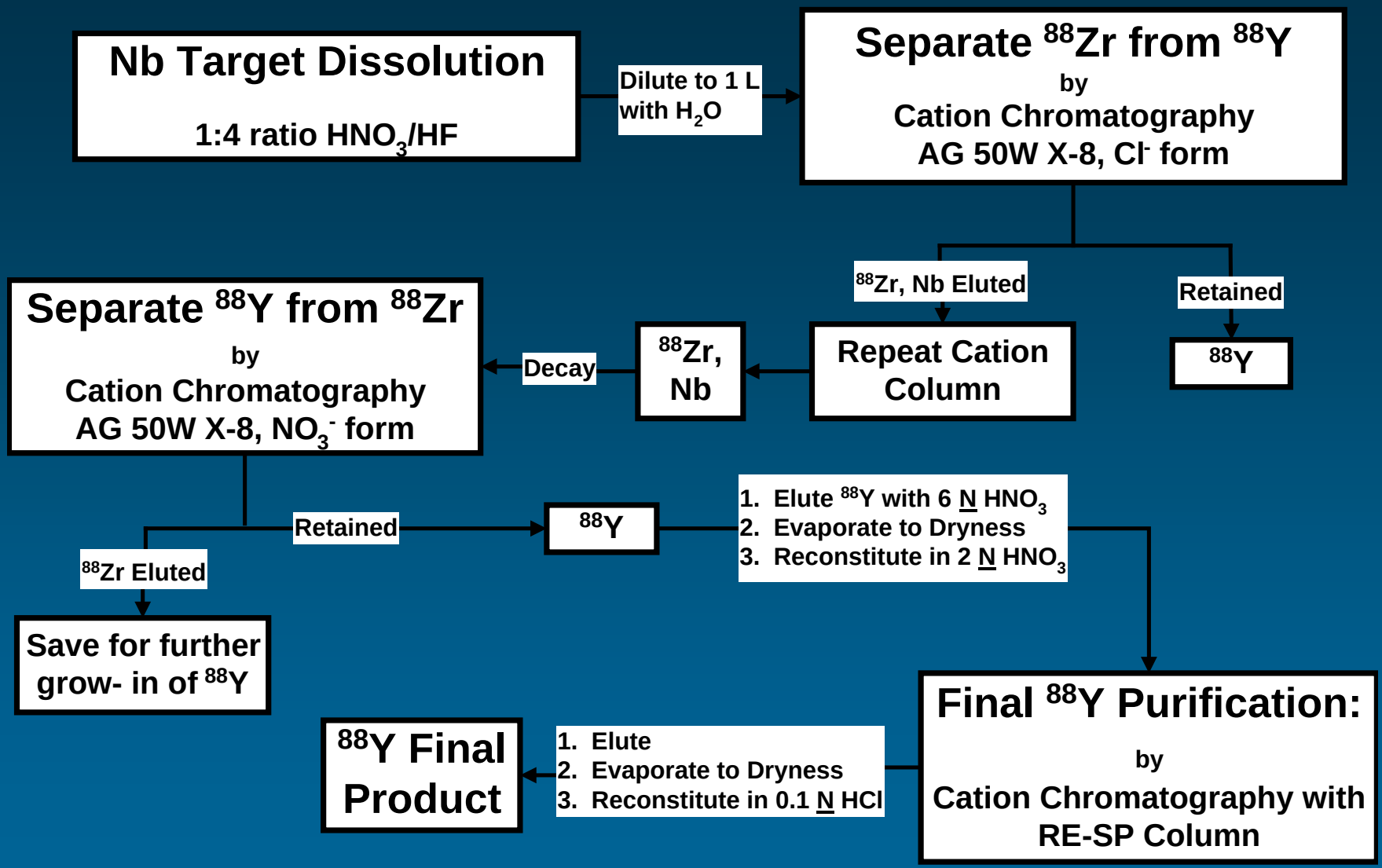
# Development of Y-88

- Half life = 106.6day decay by electron capture
- Emissions = Eγ 898 KeV (94%), 1836 KeV (99.4%)
- Used as gamma ray detector calibration source and imageable substitute for $^{90}Y$ during radiopharmaceutical development
- Produced as a byproduct in Nb target capsule containing Ga metal for Ge-68 production
- Reaction is $^{93}Nb(p,\alpha 2n)^{88}Zr$ followed by EC decay to $^{88}Y$

# Irradiation

- Two Ga targets with 0.051cm thick by 6.98cm diameter Nb windows were irradiated in BLIP for approximately one month
- Proton energy incident on the windows was 63.6, 42.7, 31.4, and 0 MeV, with an energy loss of 2.8 MeV in each
- The integral beam current was 35,411μAh

# $^{88}$Y Recovery from Proton Irradiation of Nb



# Results

- 4.3 GBq of Zr-88 recovered, purified of all Y-88
- After 44d of decay, 8.9GBq of Y-88 grew in
- 8.2GBq of Y-88 recovered, 92% yield
- Radiopurity >99.999%
- Specific activity ~29Ci/mg (carrier free)
- Isotope will be available for distribution next week

# Acknowledgements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