



THE HENRYK NIEWODNICZAŃSKI
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Production of radionuclides at a future liniac

(NZ 64)

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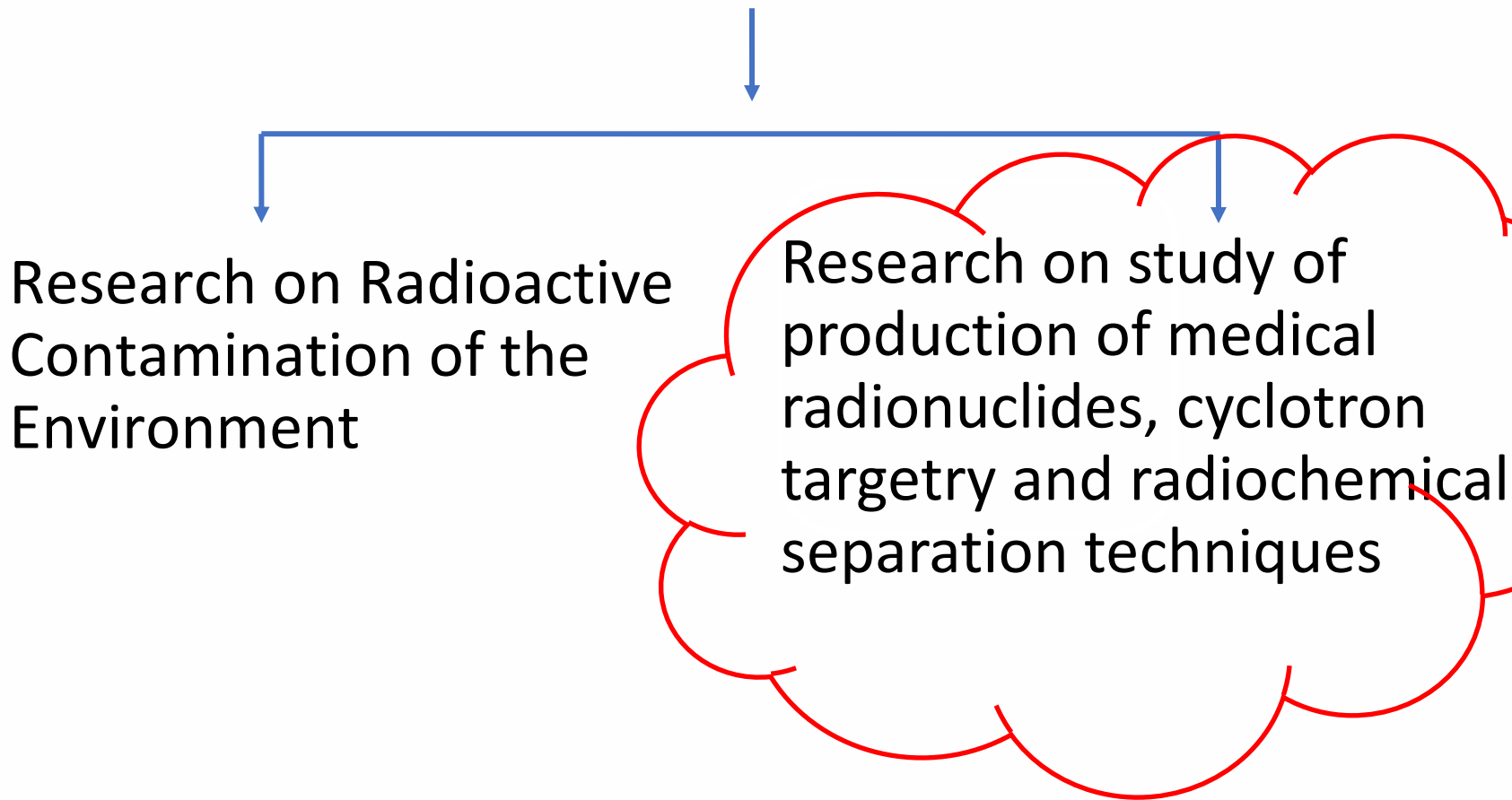
NZ-64 Nuclear Physical Chemistry (IFJPAN)

13/04/2023

Liniac at NZ64



Dept. of Nuclear Physical Chemistry (NZ64)





Current status of accelerator



Cyclotron AIC-144

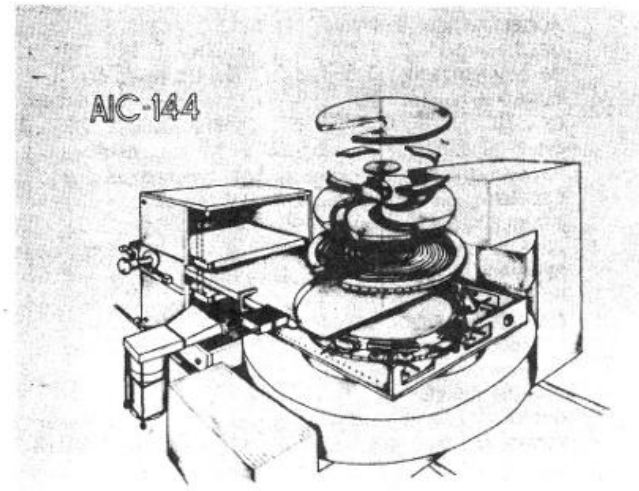
- **Proton Beam parameters**

- Energy – 60 MeV

- Current (@ shutter) < 60 nA

At target station max 40 nA

PLAN VIEW OF FACILITY, COMMENTS, ETC.



Research / Research-Capable Cyclotrons in Europe with Proton Beam > 40 MeV



Locations approximate. Criterion: proton beam > 40 MeV.

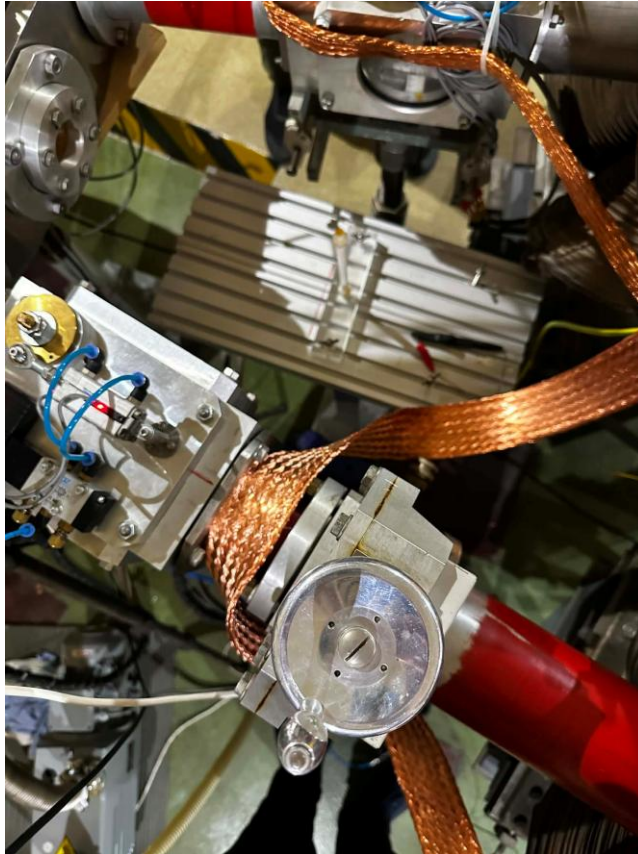
- 1 UCLouvain Cyclotron Resource Centre**
Louvain-la-Neuve, Belgium
65 MeV
- 2 JYFL K-130**
Jyväskylä, Finland
up to 85 MeV
- 3 ARRONAX**
Nantes/Saint-Herblain, France
70 MeV
- 4 INFN LNL SPES**
Legnaro, Italy
70 MeV
- 5 Trento Proton Therapy Centre**
Trento, Italy
70–230 MeV
- 6 IFJ PAN / Cyclotron Centre Bronowice**
Kraków, Poland
60 MeV and 70–230 MeV
- 7 PSI HIPA**
Villigen, Switzerland
590 MeV



Research equipment

- **α , β , and γ spectrometers**
 - Identification and quantification of radioactive material separated from irradiated targets
 - Qualitative and quantitative analysis of various radiochemicals
 - HPGe detectors and liquid Scintillation spectrometers
- **Radiochemical Laboratory (II class)**
 - Ion exchange / extraction chromatography
 - Thermochromatography
 - Microwave digestion system
 - Radiochemical box with target transport system
 - Targetry equipment (hydraulic press etc.)

Laboratory and department Staff ready for operating with high activities – in future possible upgrade for GMP standard



Typical irradiation routine for cross-section studies:

- Stacked foils / tablets with beam current and energy monitors (Al, Cu, Ti)
- Three irradiations per experiment to cover energy range up to ~60 MeV
- Gamma ray spectrometry, radiochemical separation for alpha or beta counting if required





Research (general overview)

- Nuclear reaction cross-section measurements for radioisotopes production ($T_{1/2} \geq 3\text{h}$ up to several days)
- Testing and development of radiochemical separations procedures
- Studies on obtaining (activation and separation) of radioactive tracers (^{148}Gd , ^{235}Np , ^{97}Tc) as support for environmental radioactivity monitoring and research



Recently completed projects

- Beam monitoring
- Testing of new materials for energy degradation
- Study of proton induced excitation functions on ^{70}Ge
- $^{\text{nat}}\text{Ge}$ (p,x) reactions studying $^{68}\text{Ge}/^{68}\text{Ga}$
- $^{\text{nat}}\text{Pr}$ (p,x) $^{140}\text{Nd}/^{140}\text{Pr}$
- $^{\text{nat}}\text{Zn}$ (p,x) reactions cross sections



Current work and future plans

Study on production of medical radio-generators

- $^{72}\text{Se}(T_{1/2} = 8.4 \text{ d}) / ^{72}\text{As}(T_{1/2} = 1.08 \text{ d})$, (p,x) reaction on $^{\text{nat}}\text{As}$ up to 45 MeV
- $^{194}\text{Hg}(T_{1/2} = 444 \text{ y}) / ^{194}\text{Au}(T_{1/2} = 38 \text{ h})$, $^{\text{nat}}\text{Au}$ target up to 60 MeV (a third year activation on a beam shutter)
- $^{178}\text{W}(T_{1/2} = 21.5 \text{ d}) / ^{178\text{m}}\text{Ta}(T_{1/2} = 9.3 \text{ min})$, 20-60 MeV range in $^{\text{nat}}\text{Ta}$

Other research projects

- $^{235}\text{U}(p,n)^{235}\text{Np}$ cross section study for production novel MS radiotracer
- New degrader materials testing (low scattering and neutron emission – e.g. B_4C)
- Study of $^{\text{nat}}\text{Gd}(p,x)^{152,155}\text{Tb}$ excitation functions up to 60 MeV
- Participation in future IAEA CRP for radioisotope production



Desired beam ions

Primary Particle:

- [x] Proton (p^+)
- [x] Deuteron ($2H^+ / d$)
- [x] Alpha ($4He^{2+}$)
- [x] Lithium-7 ($7Li^{3+}$)
- [x] Other (e.g., $16O^{8+}$)





Energies

Acceleration Stage (Energy):

Section 1: 2.5 MeV/u

Section 2: 12.5 MeV/u

Section 3: 250 MeV/u (Future expansion / High energy)

Custom Energy: _____ MeV/u (Variable range within section limits)



More details

Intensity / Current:

Required current on target: 0.0001 – 0.1 mA

High intensity requirements (if applicable): \approx 1 mA (in special cases)

Time Structure:

Pulse repetition rate: 100 ns | 200 ns | 400 ns | Other: n/a

Bunch width (Sigma/FWHM): < 0.5 ns

Requirement for zero dark current (no background between pulses)

Beam Spot Geometry:

Desired spot size on target: \approx 10-15 mm or larger

Requirement for no beam halo

Energy Resolution:

ΔE requirement: ~ 0.5 MeV

6. Additional Infrastructure Needs

Modification/upgrade of existing hot cell or construction of brand new lab for processing of irradiated targets, transport of targets to radiochemical lab together with targetry preparation bench/workshop:

- Box renovation (new equipment, restoration and testing of target transport system, installation of area monitoring)
- Glovebox stations for target preparation / separation in inert atmosphere
- New targetry workbench for construction of cooled targets, gas targets etc.





CONCLUSIONS

Planned is obtaining various radionuclides for both medical application and tracers for radiochemical analyses. If routine work for medicine a special devoted team needed.

To obtain maximum flexibility in future studies a wide range of beam particles as well as energies are desired.

High current of beam would be the key feature enabling obtaining sufficient activities for medical applications.

The heavy ion beams are of the particular interest due to opening room for production of radioactive tracers not available in (p, xn) or (d, xn) reactions.

For production of tracers high currents are not necessary. High energy will open also opportunity to use spallation for radionuclide production, what sometime is a only one way of production of desired nuclide.

Therefore, for proposed here purpose a wide range of beam particles and also energies as well as high current are required.