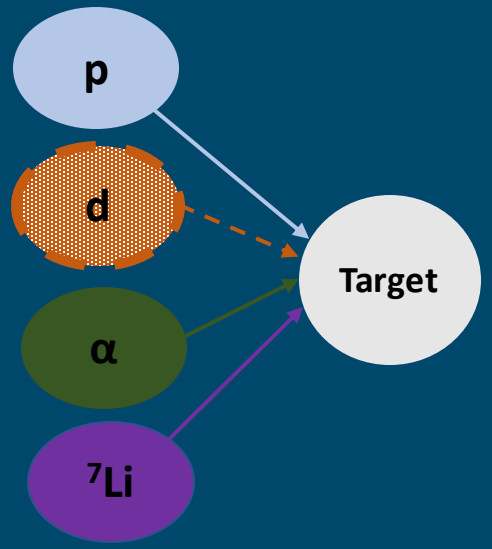
THE HENRYK NIEWODNICZAŃSKI
INSTITUTE OF NUCLEAR PHYSICS
POLISH ACADEMY OF SCIENCES

3rd Workshop on Research and Innovation in Poland

Multi-Ion Cross-Section Studies for Radionuclide Production

From target selection to production yield and radionuclidic purity at the future IFJPAN LINAC



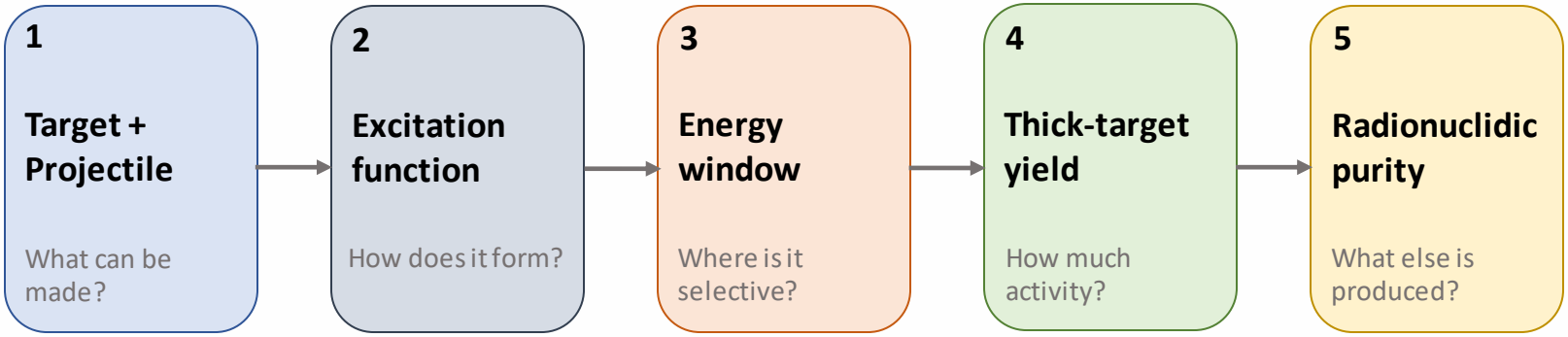
One Facility, Multi-Ion Projectiles,
One Decision Framework

Dr Arshiya Anees Ahmed (On behalf of NZ-64)

23rd October 2026, Cracow

Why this programme

Cross sections guide production-route selection



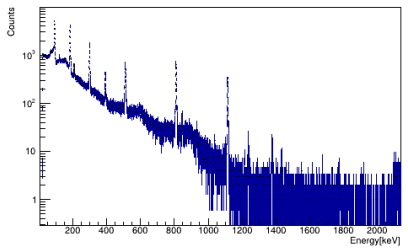
- Helps determine desired and competing reaction channels
- Stopping power connection functions to TTY
- Decay during irradiation and cooling changes the final purity

The cross section is not the final result – it is the input to an operational decision

Current work

Existing proton-activation baseline at IFJ PAN



Target systems already studied

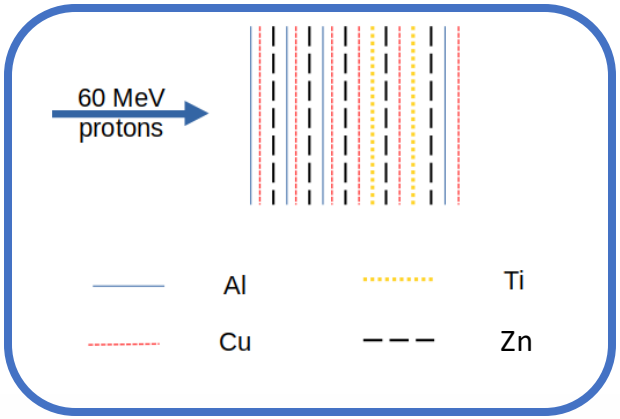
- ^{nat}Mo — $^{99}Mo/^{99m}Tc$ generator, direct ^{99m}Tc
- CaO, $CaCO_3$ — $^{43,44,47}Sc$ production and target-material comparison
- ^{nat}Ge, ^{70}Ge — As, Ga, Ge radionuclides; natural and enriched targets
- Pr_2O_3 — $^{140}Nd/^{140}Pr$ generator, chemical separation
- ^{nat}Zn — Co, Cu, Ga, Zn radionuclides
- **Tb isotopes production via IAEA CRP (on going)**

Reusable measurement workflow

1. **Stacked Foils**
   Energy degradation + monitor foils
2. **HPGe spectroscopy**
   Decay-corrected activities
3. **Transport + reaction models**
   GEANT4/SRIM/TALYS checks
4. **Decision products**
   σ (E), yield and purity

Experimental evidence

Representative case: ^{nat}Zn stacked-foil activation



Schematics of experimental setup

Monitor foils were placed before each Zn target. Beam energy and current were reconstructed across the stack

31
Zn discs

3
Irradiations

5.1-59.4 MeV
Proton energy range

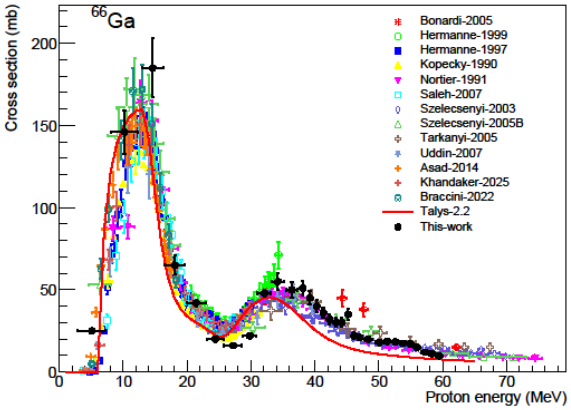
15-19 nA
Beam current

Measured product channels

^{57}Co	^{58}Co	^{60}Co
^{61}Cu	^{64}Cu	^{67}Cu
^{66}Ga	^{67}Ga	^{68}Ga
^{62}Zn	^{65}Zn	^{69m}Zn

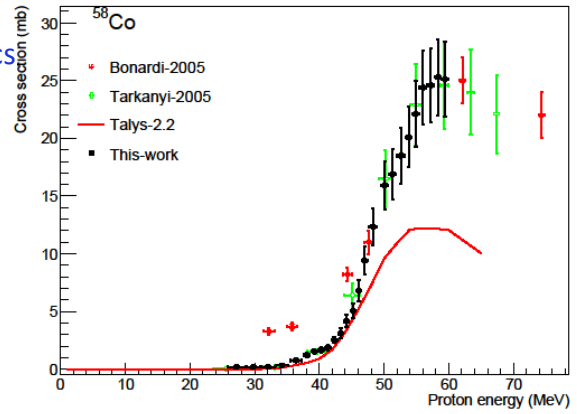
Experimental evidence

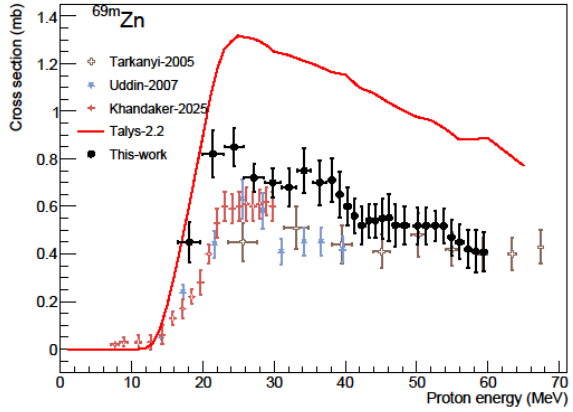
Representative case: ^{nat}Zn stacked-foil activation



^{66}Ga: $T_{1/2}$= 9.49 h
PET imaging

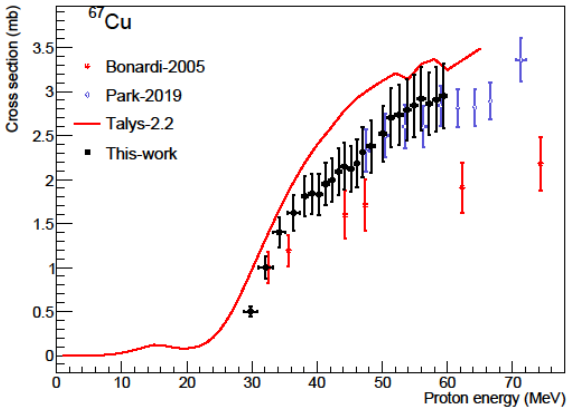
^{58}Co: $T_{1/2}$= 70.856 d
PET tracer and theranostics with ^{58m}Co (Auger)





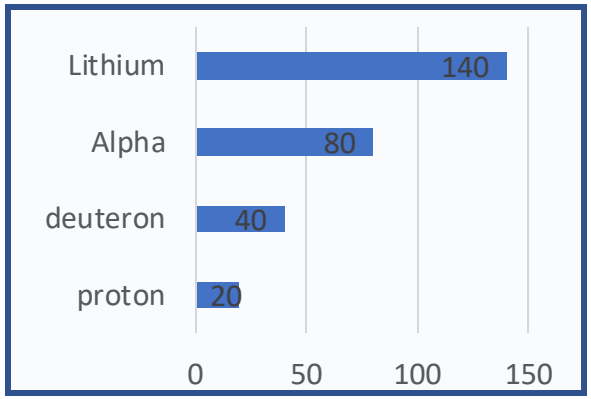
^{69m}Zn: $T_{1/2}$= 13.56 h

^{67}Cu: $T_{1/2}$= 61.83 h
Targeted radionuclide therapy, theranostic with other Cu isotopes



Why LINAC

Multi-ion activation expands the reaction space



Maximum total energy at 20 MeV/u

Proton

Reference beam

Established activation methods and monitor reactions

Deuteron

Transfer and breakup reactions

(d,n), (d,p), and (d,xn) production routes

Alpha

Direct alpha-induced production

(α,xn) routes to neutron-deficient products

^{7}Li

Distinctive heavy light-ion capacity

Fusion, transfer, breakup and generator routes

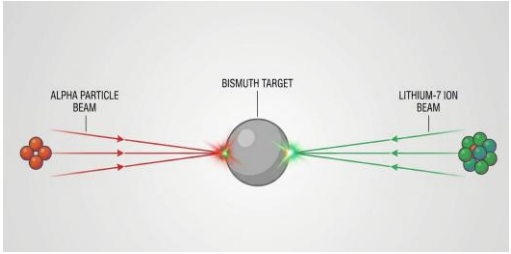
The new LINAC will complement AIC-144: proton data anchor the method; d, α, ^{7}Li open routes that protons cannot reproduce.

Case 1

^{211}At: the flagship multi-ion decision experiment

^{209}Bi(α,2n)^{211}At

Direct production



^{209}Bi(^{7}Li,5n)^{211}Rn -> ^{211}At

Generator

- Established production pathway
- Alpha energy around 28-29.5 MeV
- Critical impurity ^{210}At -> ^{210}Po
- Very precise energy control required
- Logistical challenges due to its 7.2-hour half-life

- ^{7}Li energy ~ 40-60 MeV
- ^{211}Rn half-life ~ 14.6 h
- Potential generator for ^{211}At
- Very limited cross-section, impurity and breakup channel data
- Thick target ^{211}Rn yield

Case 2

^{119}Sb: a high-potential route that still needs nuclear data

^{119}Sn(p,n)^{119}Sb
Established

- Requires p energy below 15 MeV
- ^{119}Sn is 8.59% in natural Sn
- Reference for purity and yield

^{118,119}Sn(d,xn)^{119}Sb

- d energy ~ 3-20 MeV
- ^{118}Sn is 24.22% in natural Sn
- No reliable enriched target experimental excitation functions
- Test the deuteron models and ^{118m,g}Sb formation

^{117}Sn(α,2n)^{119m,g}Te -> ^{119}Sb

^{nat}Sn(α,xn)^{119m,g}Te,^{119}Sb

- α energy ~ 18-45 MeV
- Generator ingrowth and separation
- Very limited cross-section, isomeric ratio, cumulative ^{119}Sb production

What the LINAC must enable

Requirements for a multi-ion activation programme

01

Beam control

Tunable energy
Stable low-current mode
Reliable charge integration

+

02

Target engineering

Thin foils + thick targets
Active cooling
Remote, repeatable geometry

+

03

Nuclear metrology

Monitor reactions for each ion
Energy-loss verification
Traceable uncertainty budget

+

04

Fast post-irradiation chain

Rapid transfer
HPGe + radiochemistry
Hot-cell / target recovery

Conclusions

- Proton work provides the validated experimental baseline
- Deuteron, alpha and lithium beams enable direct and generator-based radioisotope studies.
- Cross-sections lead to energy-window, yield, and radionuclidic-purity decisions.

Thank You

