Proposal for Beam Time and Research Program at IFJ PAN LINAC

1. General Information

Project Title: Half-life measurements of long-lived isotopes

Principal Investigator (PI): Ł. W. Iskra

Co-Investigators / Research Team: B. Fornal, K. Gajewska et al.,

2. Particle and Energy Selection

Please check the required particle and the target energy section:

Primary Particle:

[ ] Proton (p+)

[ ] Deuteron (2H+ / d)

[ ] Alpha (4He2+)

[x] Lithium-7 (7Li3+)

[ ] Other (e.g., 16O8+): fast neutron after p + Li or (d,n) reactions

Acceleration Stage (Energy):

[x] **Section 1:** 2.5 MeV/u

[x] **Section 2:** 12.5 MeV/u

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

[ ] **Custom Energy:** _________ MeV/u (Variable range within section limits) Fast neutrons with energies of 8–19 MeV are produced via reactions induced by **a ^{7}Li beam with energies of 25–50 MeV**.

3. Abstract of Planned Research

(Provide a brief description of the experiment, its scientific goals, and the expected outcome – max 300 words)

The experiment aims to determine the half-lives of long-lived isotopes formed via β^- decay of short-lived parent nuclei. These precursors will be produced through (n,α) reactions and transported to a dedicated facility for activation measurements. The results are important for reactor physics, astrophysics, and nuclear medicine. Fast neutrons in the range of 8–19 MeV can be generated via the ^{7}Li + p → ^{7}Be + n reaction using ^{7}Li at energies of 25–50 MeV. Traditional decay-curve methods are unsuitable for isotopes with lifetimes of hundreds of years or more. Instead, half-lives can be derived by comparing absolute activity with the total number of atoms. This approach is challenging because long-lived isotopes often emit little or no gamma radiation, and atom-counting techniques introduce significant systematic uncertainties. Consequently, many published half-life values remain inconsistent. For example, the nuclear waste isotope ^{93}Zr has reported half-lives of $1.64(6) \times 10^6$ years and $1.13(11) \times 10^6$ years, differing by more than 500,000 years. Likewise, ^{79}Se, relevant to both astrophysics and waste management, has values ranging from $9.15(45) \times 10^4$ to $1.1(2) \times 10^6$ years, compared to an adopted value of $3.27(28) \times 10^5$ years. Other long-lived isotopes of interest include ^{107}Pd, ^{135}Cs, and ^{129}I, the latter widely used as a geological and biological tracer. The proposed method improves accuracy by generating the nuclei of interest through β decay of

short-lived precursors that can be precisely quantified via gamma spectroscopy. These precursors are created using high-intensity neutron-induced reactions. In the case of ^{93}Zr, irradiation of stable ^{96}Zr produces ^{93}Sr, which decays to ^{93}Y, emitting characteristic gamma rays. The subsequent decay of ^{93}Y to ^{93}Zr also produces identifiable gamma emissions. By measuring these signals, the number of ^{93}Zr atoms can be determined, enabling a more reliable half-life evaluation without interference from its weak β^- decay.

4. Technical Beam Requirements

Please specify the desired beam parameters to ensure the feasibility of the experiment:

Intensity / Current:

Required current on target: _________ (e.g., 10 pA – 10 nA)

High intensity requirements (if applicable): 1 mA

Time Structure:

Pulse repetition rate: [ ] 100 ns | [] 200 ns | [] 400 ns | [ ] Other: continuous beam

Bunch width (Sigma/FWHM): < 0.5 ns

[ ] Requirement for zero dark current (no background between pulses)

Beam Spot Geometry:

Desired spot size on target: _________ mm (e.g., < 0.5 mm)

[x] Requirement for no beam halo

Energy Resolution:

ΔE requirement: <100 keV (e.g., < 10 keV)

5. Application Category

[x] **Fundamental Nuclear Physics**

[ ] **Medical Applications**

[ ] **Electronics Irradiation**

[x] **Material Science / Biophysics**

6. Additional Infrastructure Needs

- Detectors – two HPGe, proportional gas counter

- A dedicated area with very low background for activation measurements.