Enabling direct reaction studies with small, highly radioactive samples

Brad DiGiovine
P-3, Physics Division

1 March 2022

LA-UR-22-21560
Direct reaction studies on radioactive samples

Chemistry

Instruments, Infrastructure and Execution

Sample Production
Experiments

hotLENZ Instrument
- For \((n,z)\) studies
- \(^{56}\text{Ni}\) sample e-plated on thin Au foil
- Custom tungsten instrument cask
- Remote operations

DICER Instrument
- For \((n,\text{tot})\) studies
- Simultaneous sample in-out measurement
  - Ø1mm binocular collimation, 30m long system
  - “Thick” samples for transmission measurements
- \(^{88}\text{Zr}\) sample in 2M DCI D\(_2\)O solution
- Self shielding hermetic sample container
Chemistry

• Remote operations in hot cells
• Chemical separation of irradiated production target, fab prep
• Identification and quantification of sample material and contaminants
• Speed and efficiency of operations
Sample Considerations

- **Sample form factor**
  - Thin platings
  - Aqueous solutions

- **Sample material location**
  - Limited material
    - Production
    - Dose considerations
  - Beam/target overlap critical

- **Neutronics**

- **Chemical compatibility**

Aqueous solution Ø1mm x 10mm

Tungsten container Ø10mm x 15mm

DICER $^{88}$Zr

Ø2mm Aluminum beam window

Galvanic corrosion

Ø6mm deposition

hotLENZ $^{56}$Ni

Custom self-locating e-plating gasket
Sample Production

- Remote operations in hot cells
- Sample production techniques
  - Electroplating
  - Hermetically sealed
- Packaging and transport

Automated microliter dispensing system

On-board inspection camera snapshots

Inspection Camera

Microliter syringe driver

Sample alignment stage

Driven linear stage
Instruments, Infrastructure and Execution

$^{56}$Ni with hotLENZ @ WNR

- Facility-flightpath-instrument optimization
  - Holistic approach to design
  - Modern metrology→T4Gen2
  - Advanced collimation
  - Precision alignment

- Safety
  - Radiation safety
    - Remote operations
    - Shielding
  - Cold runs

Spallation target metrology testing

Instrument cask

Remote manipulation system arm

8.25m

WNR facility spatial data set

Instrument, collimation, and sample aligned to < 10μm from nominal
Instruments, Infrastructure and Execution

56Ni instrument cask loading

Advanced collimation for precision (n,z) studies

56Ni instrument cask installation

56Ni – sample transport basket

Cask is inside chamber

hotLENZ instrument assembly

Flight path shutter

hotLENZ ready for 56Ni study

56Ni - instrument cask transport

hotLENZ ready for 56Ni study
Instruments, Infrastructure and Execution

\(^{88}\text{Zr}\) with DICER @ Lujan

- Techniques developed from \(^{56}\text{Ni}\) campaign
  - Modern metrology
    - Laser tracker
    - Optical CMM
    - Photogrammetry
    - Structured light
  - Precision alignment
- Safety
  - Radiation safety
    - Shielding
    - Containment
  - Cold runs

Sample placement repeatability limited by sample housing manufacturing tolerances, inspected to 1\(\mu\)m with S.L.

Instrument alignment < 10\(\mu\)m from nominal along 30m flight path.
Instruments, Infrastructure and Execution

Sample holder/collimator opened and prepared for installation of $^{88}$Zr sample

$^{88}$Zr sample position

DICER instrument sample station ready for $^{88}$Zr study

Sample holder and collimator, Ø1mm binocular style with 15m focal point
Direct reaction studies on radioactive samples

• Fully integrated multidisciplinary effort
  – Systems engineering approach to design, integrate, and manage complex systems
  – Precise coordination of intricate operations across multiple teams
  – This methodology delivers the required speed and efficiency, but….

• Safety is paramount

• Direct reaction studies on many short lived radioactive isotopes is within reach!