

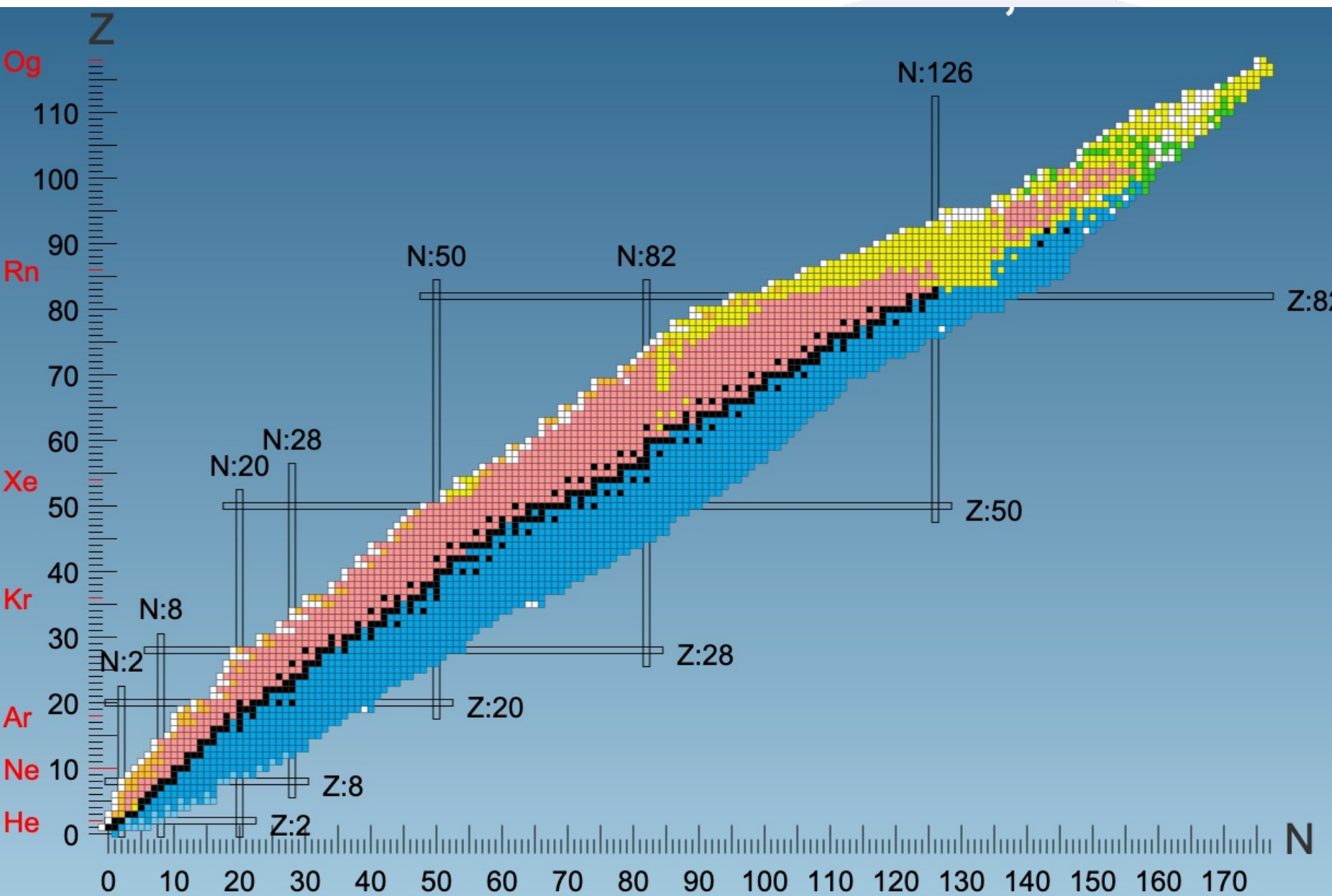
Wanted: Tiny radioactive samples for neutron transmission measurements with DICER at LANSCE

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3. Weapons Stockpile Modernization Division, Los Alamos National Laboratory, 87545, NM, USA

LA-UR-24-21823

The why



The why

(n,γ)

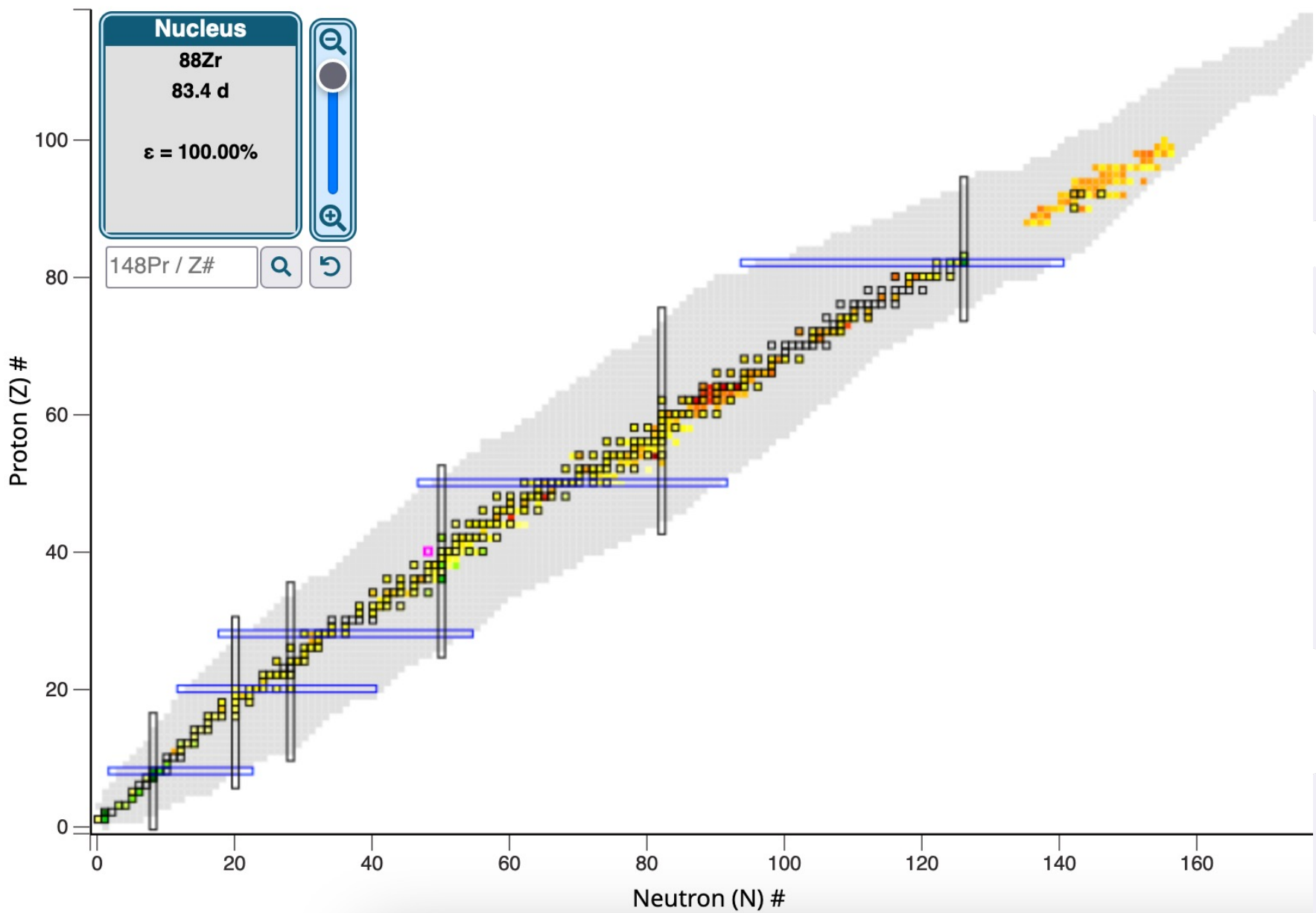


Zr 87 14.0 s 1.68 h β^+ 2.3 γ 1227 1210 IT 135, e^- γ 201		Zr 88 83.4 d ϵ γ 393		Zr 89 4.161 m 78.41 h IT 588 ϵ β^+ 0.9, 2.4 γ 1507 g		Zr 90 809.2 ms 51.45 IT 2319 133 γ 2186... σ 0.014		Zr 91 11.22 σ 1.30		Zr 92 17.15 σ 0.131	
Y 86 47.4 m 14.74 h IT (10), e^- γ 208 β^+ ... γ (1077 1153...)		Y 87 13.37 h 79.8 h IT 381 ϵ β^+ ... g		Y 88 106.626 d ϵ β^+ ... γ 1836, 898...		Y 89 15.663 s 100 IT 909 σ 0.001 + 1.279		Y 90 3.19 h 64.05 h IT 480... γ 203 β^- ... γ (2319) $\sigma < 6.5$		Y 91 49.71 m 58.51 d β^- 1.5... γ (1205) IT 556 σ 1.4	
Sr 85 67.63 m 64.849 d IT (7...) e^- γ 232 ϵ , no β^+ γ 151...		Sr 86 9.86 σ 0.791 + 0.24		Sr 87 2.815 h 7.00 IT 389 ϵ		Sr 88 82.58 σ 0.0055		Sr 89 50.563 d β^- 1.5... γ (909) g σ 0.42		Sr 90 28.91 a β^- 0.5 no γ g σ 0.010	

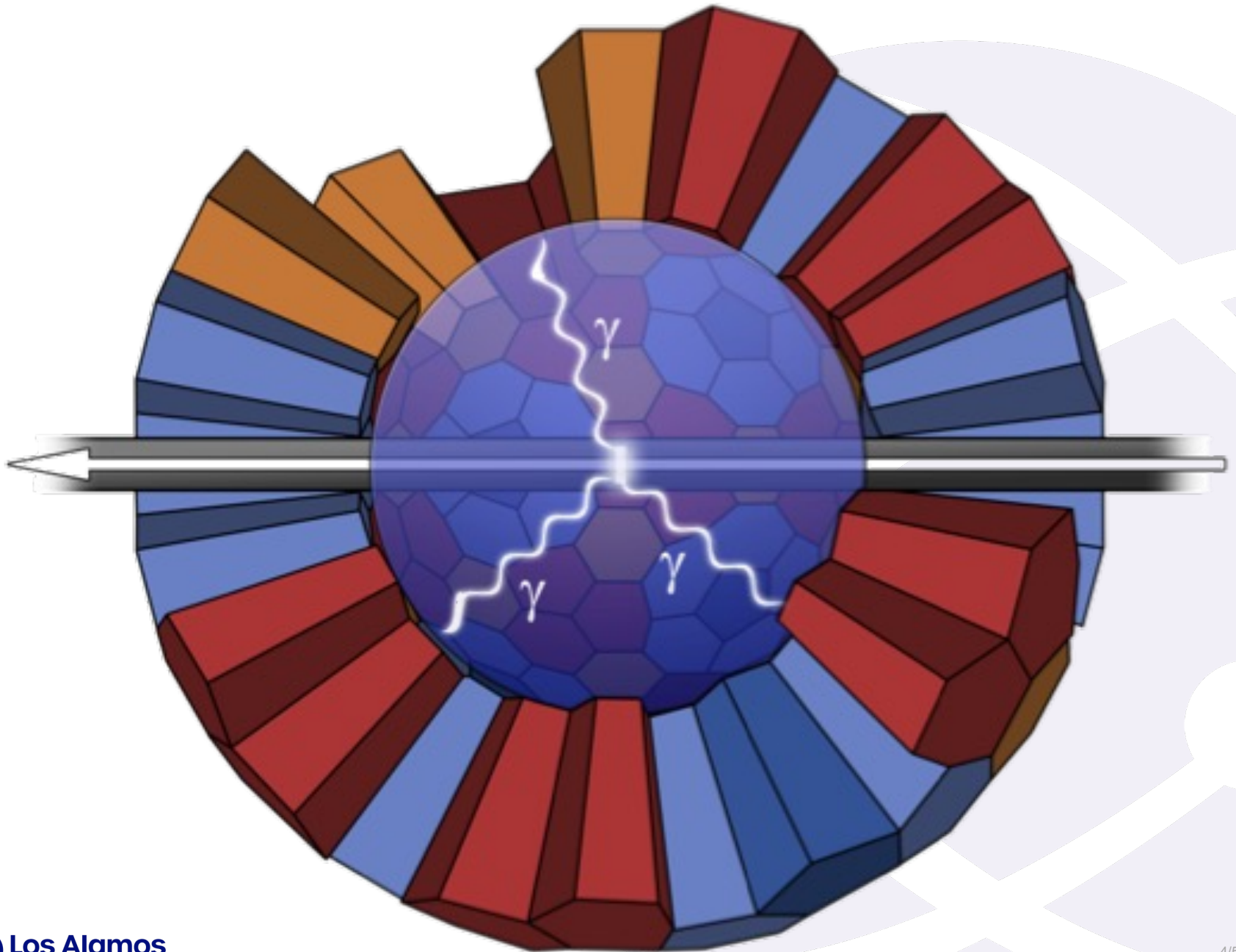


$(n,2n)$

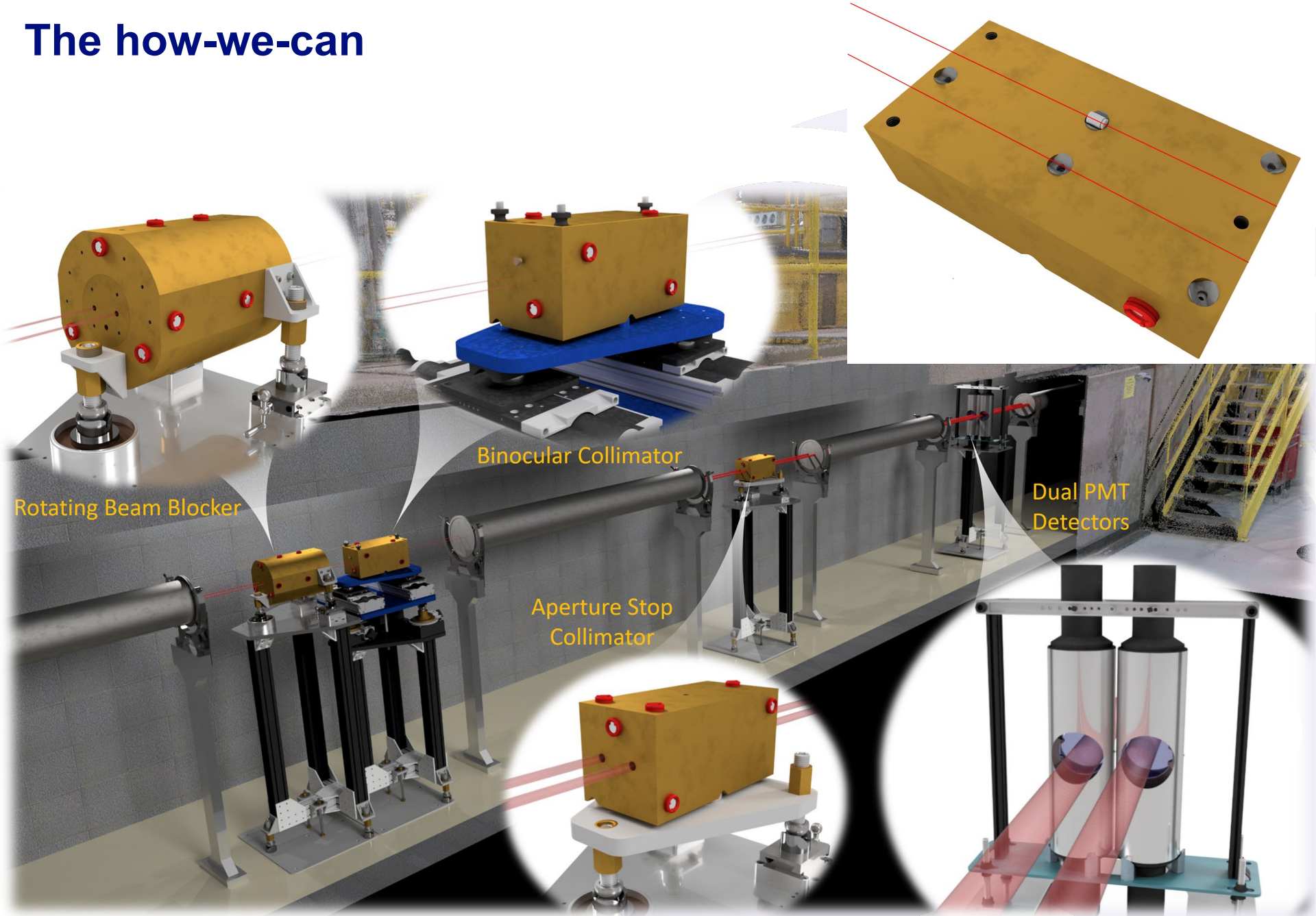
The what-we-know



The how-we-wish



The how-we-can



Rotating Beam Blocker

Binocular Collimator

Aperture Stop Collimator

Dual PMT Detectors

The where

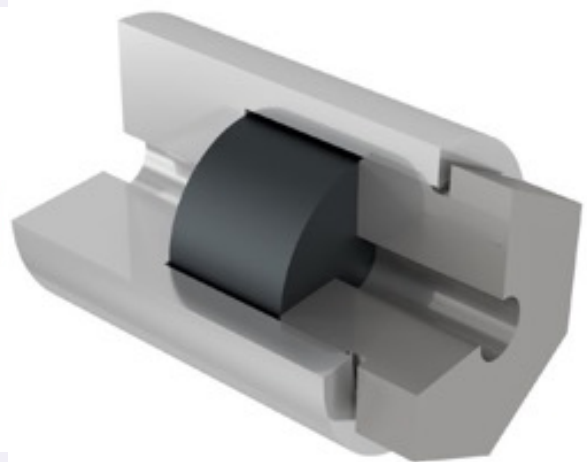
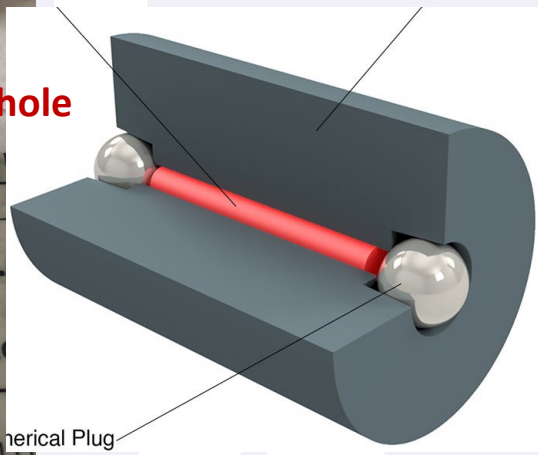
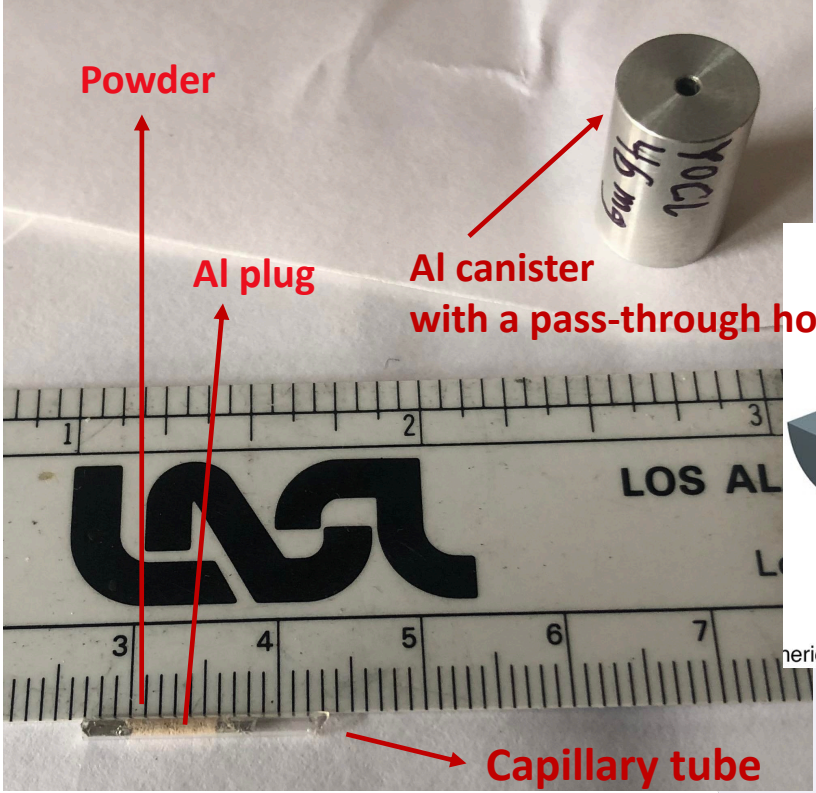
1. LANSCE@LANL
2. 1st takeaway: walking distance from IPF!
3. 2nd takeaway: A few minutes drive to the hot-cells.



A few specs

- 1. Cylinder
- 2. 1 mm or 0.1 mm diameter
- 3. 1.5 cm in length

- 4. Liquid, powder and metallic samples.
- 5. Sample canister: 1.5 cm long, 1 cm diameter
- 6. Cryogenic and gaseous targets are on the works



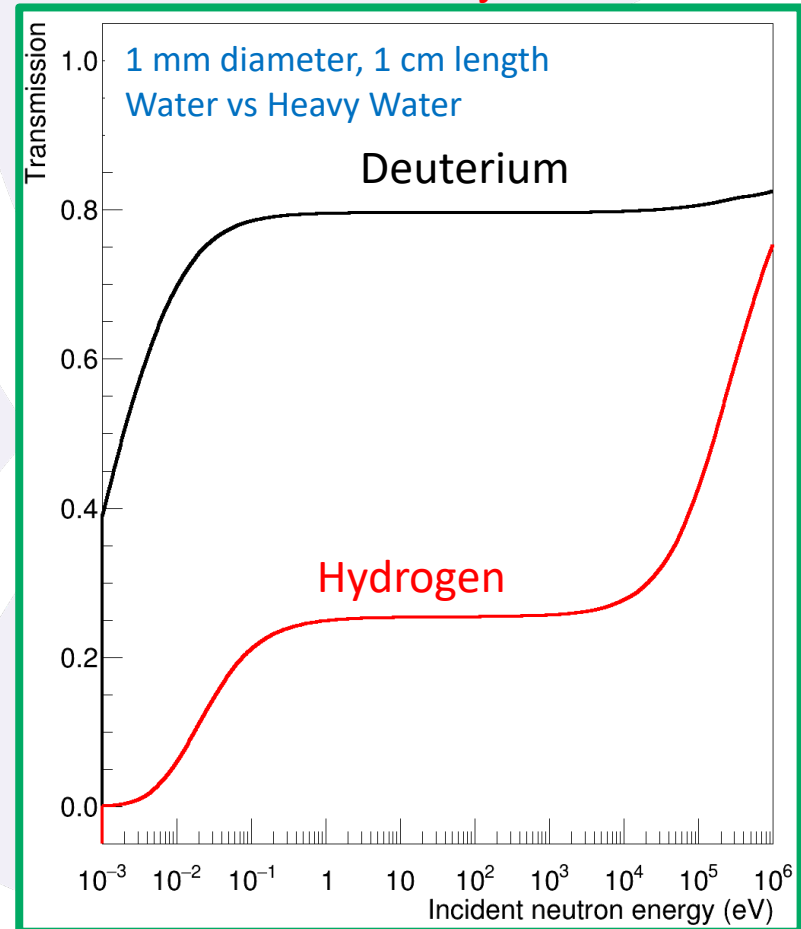
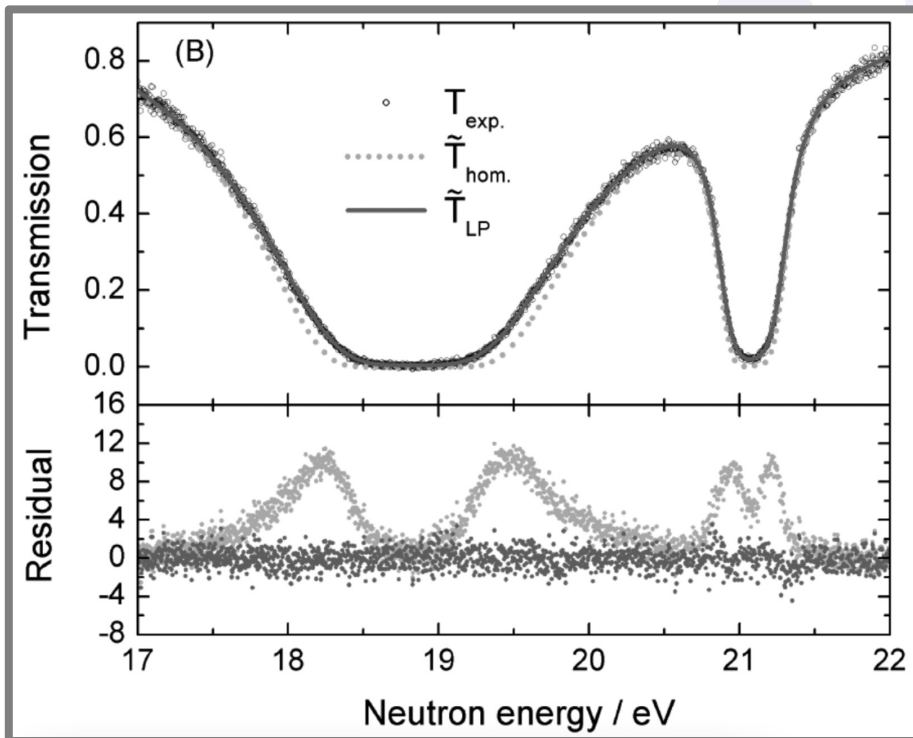
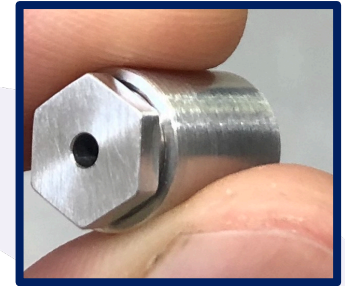
Powder sample, stuffed in a capillary tube, plugged with Al wire and placed inside an Al DICER canister

Liquid radioactive ^{88}Zr sample, dispensed in a W canister

Metallic sample (Mo, Cd, Gd) in an Al screw down canister.

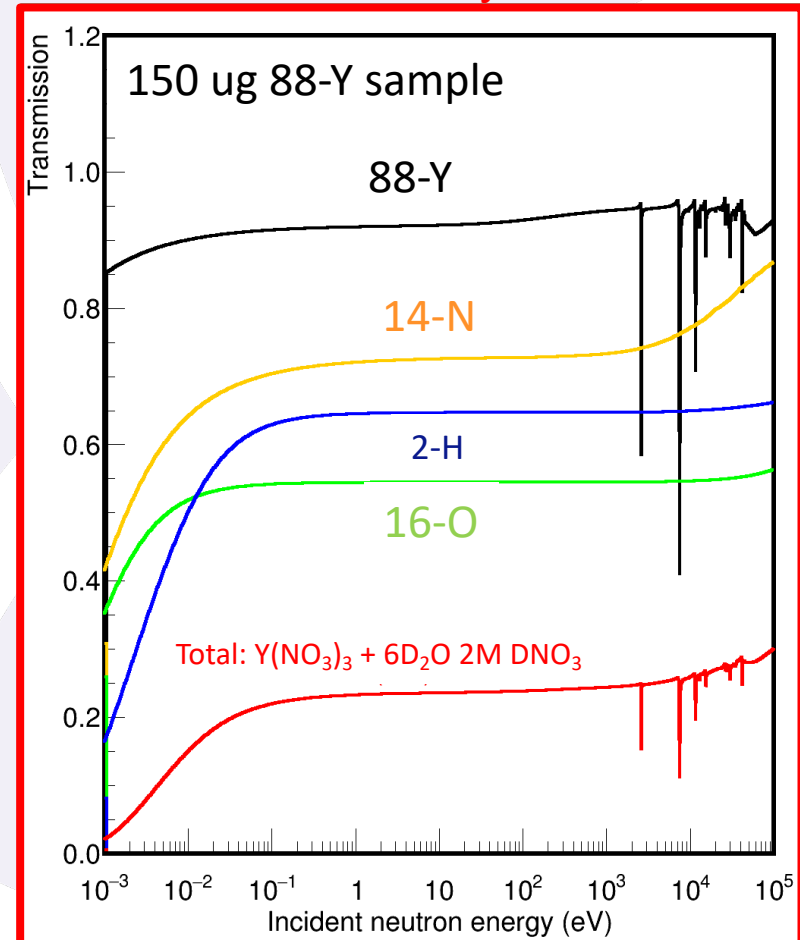
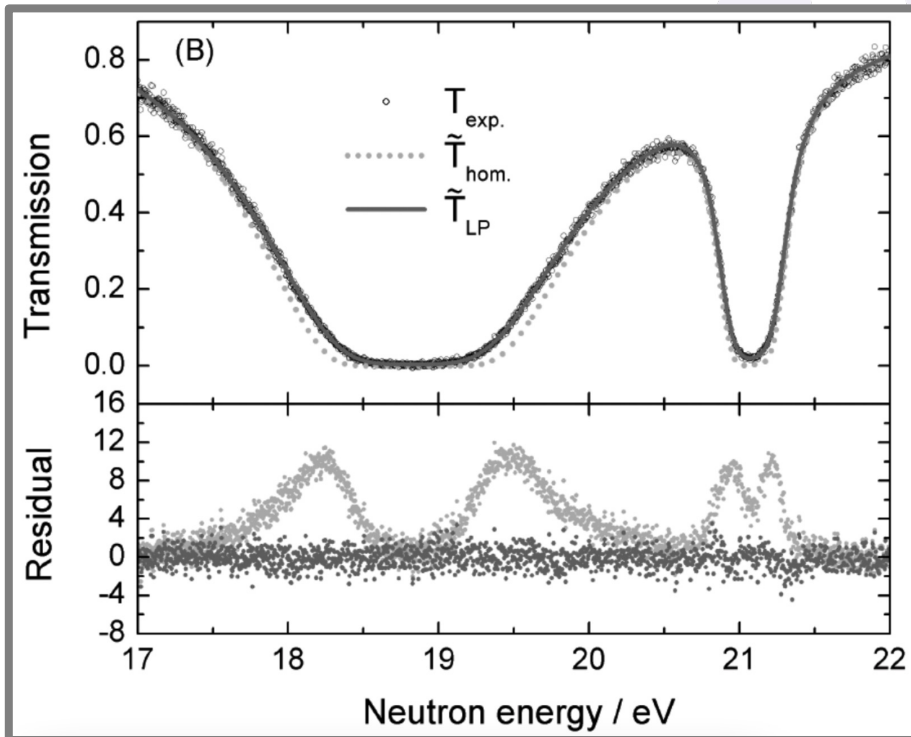
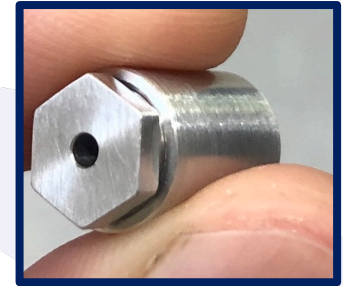
A few more specs

1. Samples should fit the DICER sample format (1/0.1 mm diameter, 1.5 cm length)
2. Uniformity and homogeneity
3. Minimization of hydrogen: replacement with deuterated compounds(?)
4. Other components in the sample, should be transmission friendly: Avoid nuclei that are neutron absorbers.



A few more specs

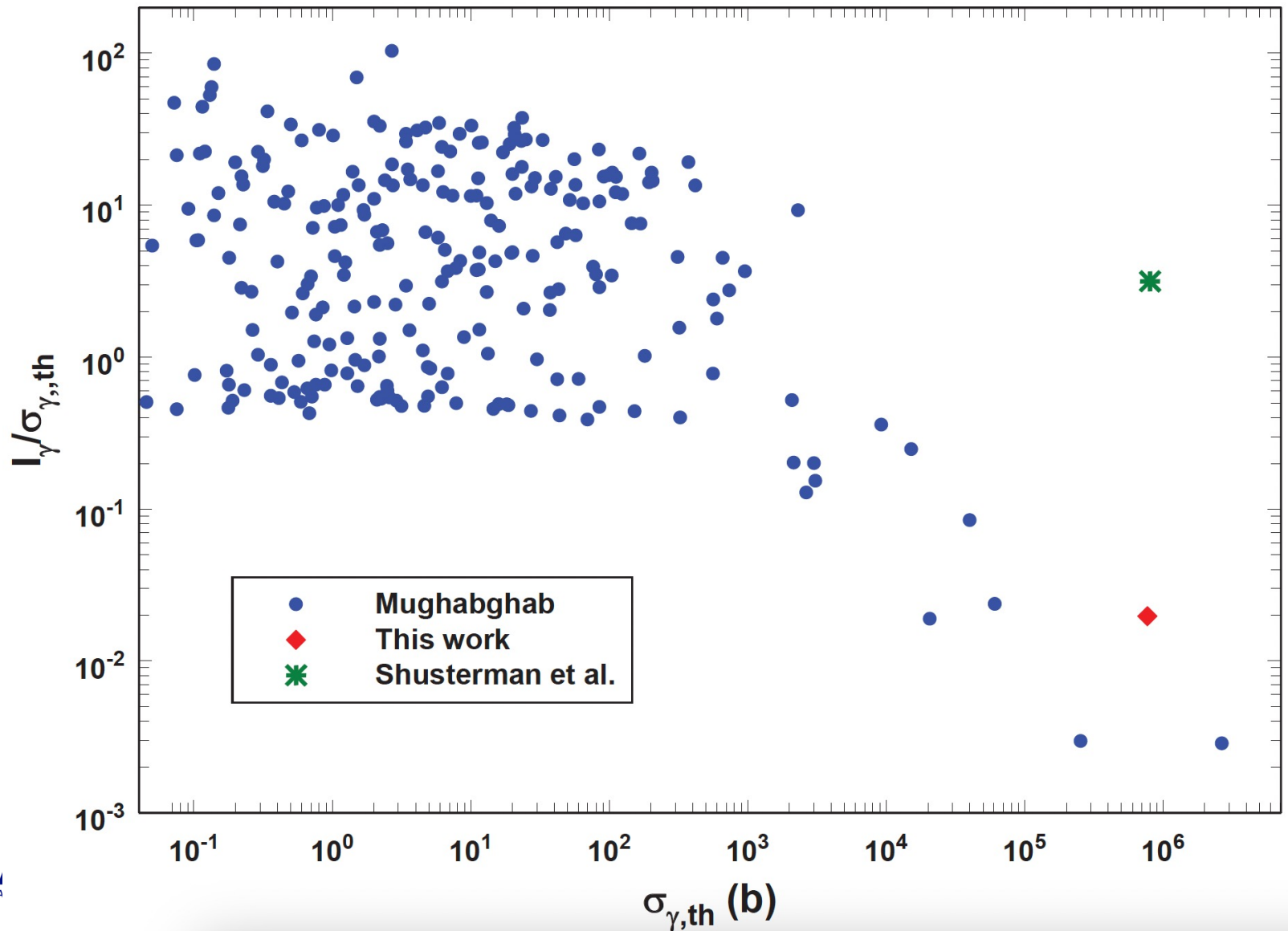
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The curious case of ^{88}Zr ($t_{1/2} = 83.4$ days)

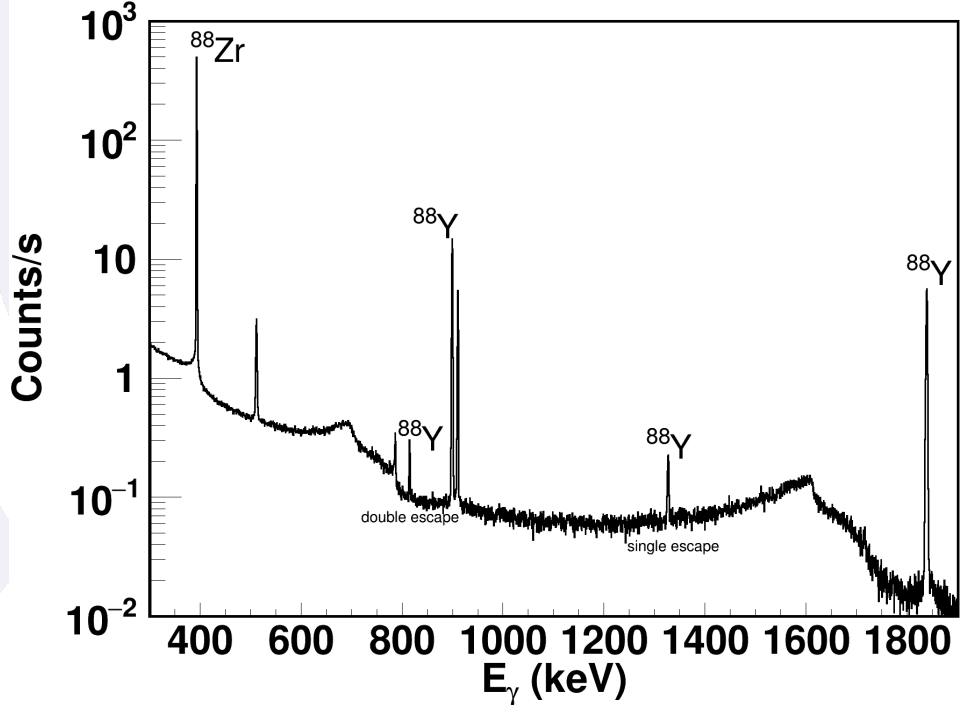
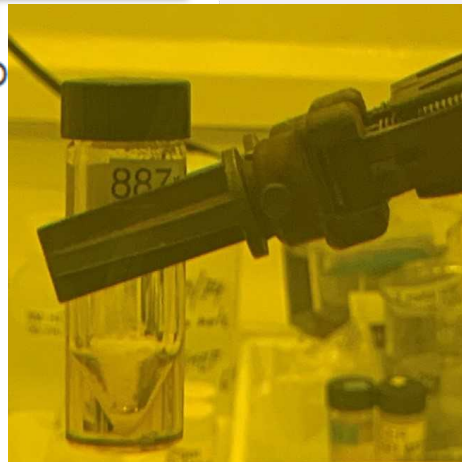
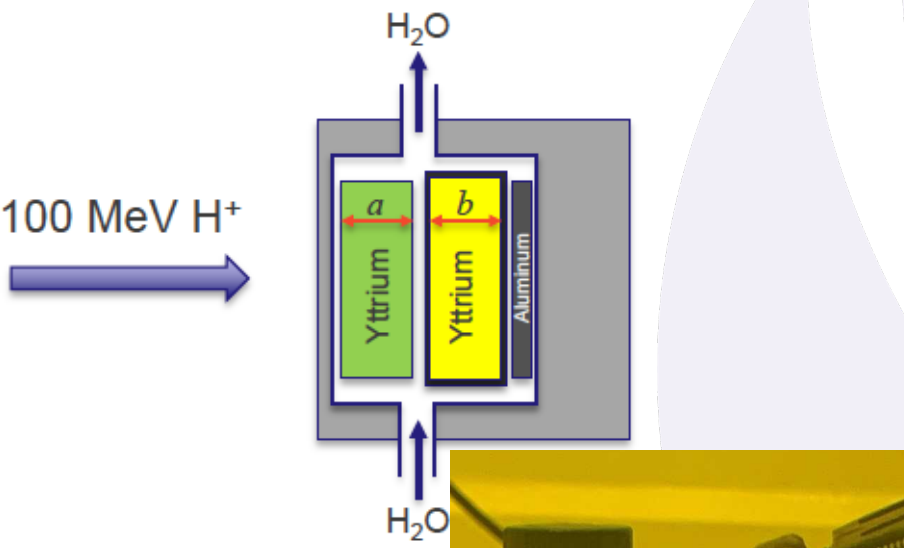
• LLNL: $\sigma_{\gamma}^{\text{th}} = 0.861(69)$ Mb
Shusterman et al., Nature 565, p 328 (2019)

• LLNL: $I_{\gamma} = 2.530(280)$ Mb
Shusterman et al., PRC 103 124614 (2021)



DICER-IPF synergy: The ^{88}Zr case aka a success story

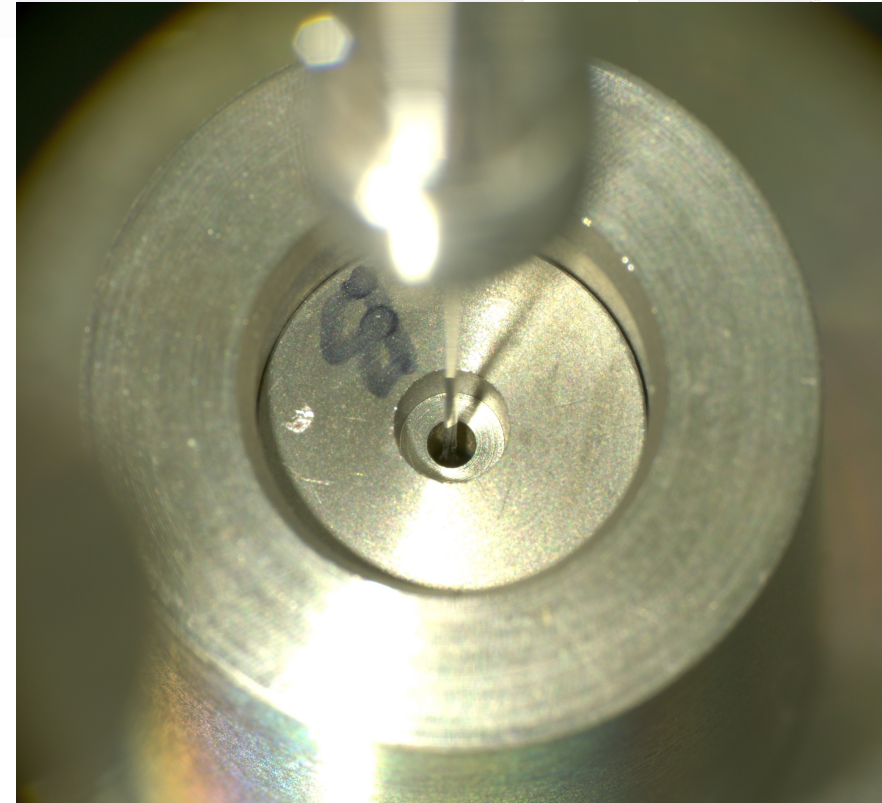
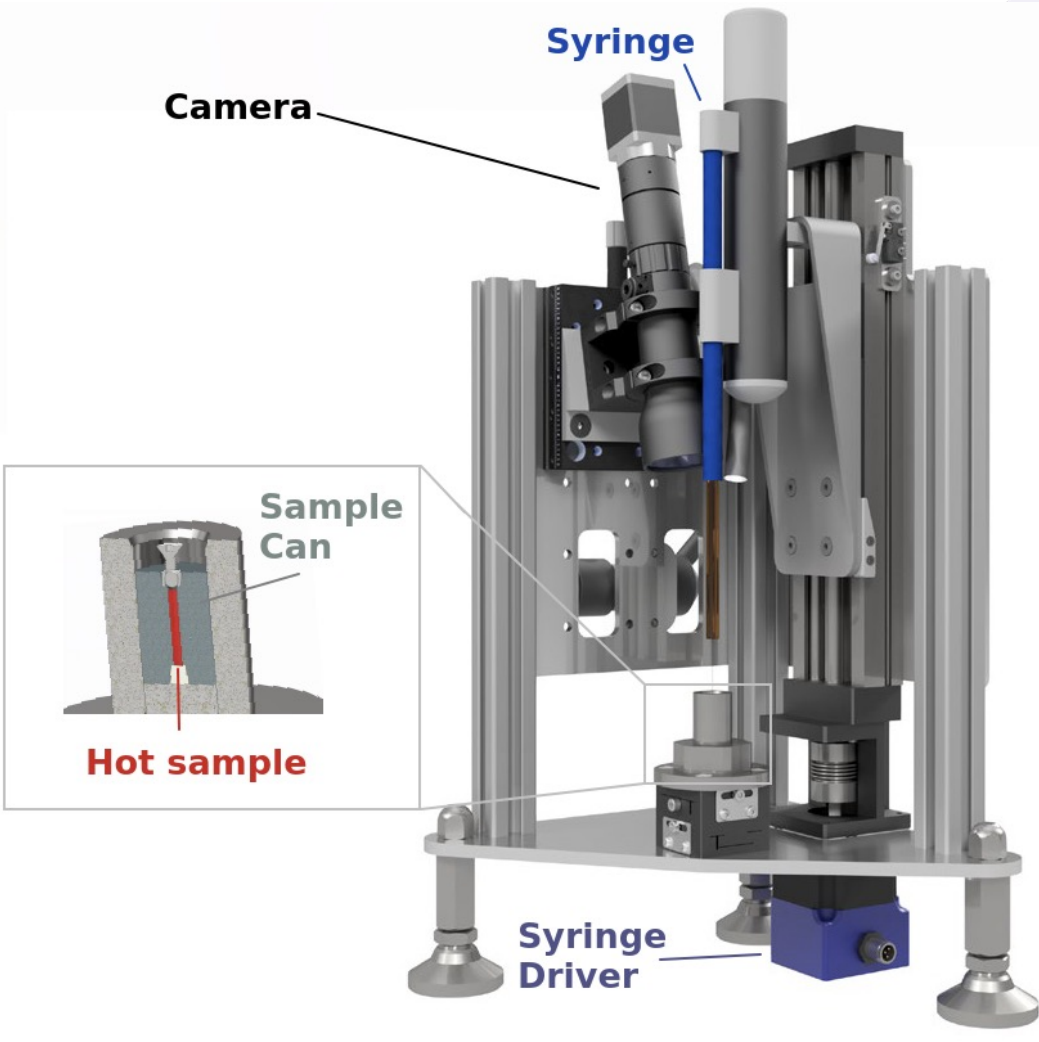
- The radioactive sample fabrication relies on the synergy between LANSCE and IPF
- Proton irradiation of a suitable bulk material (^{89}Y)
- Chemical separation and purification (600 mCi, 10 mL ^{88}Zr + $\text{H}_2\text{O} \bullet 6\text{mol/L HCl}$)
- Gamma spectroscopy to extract mass



A. Matyskin et al, Sci. Rep., 2023 13(1), 1736
A. Stamatopoulos et al., J Rad. Chem., 2022, 331(12)
A. Stamatopoulos et al., EPJ., Conf. 260, 03006 (2022)

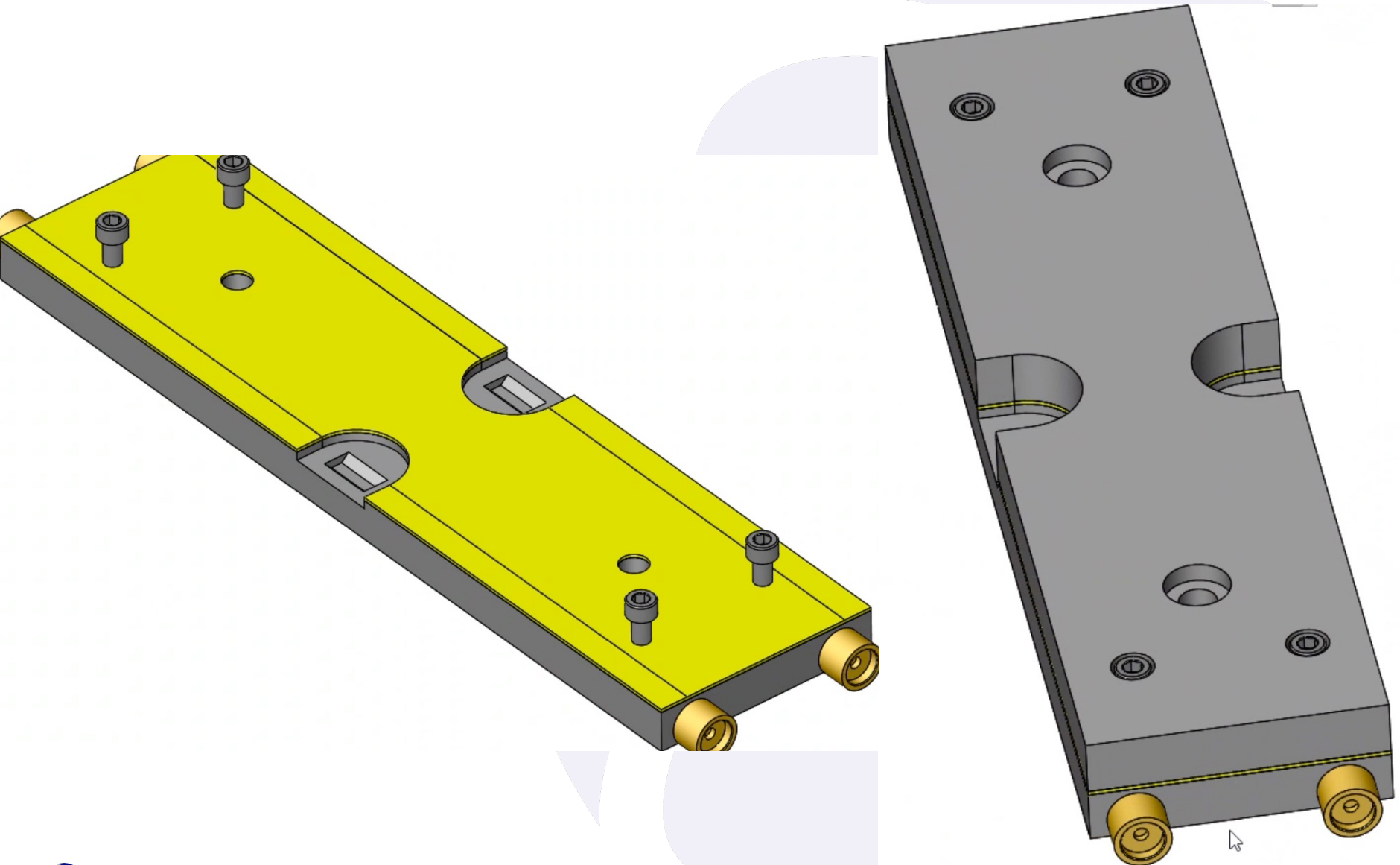
Development of filling station

- To enclose our ^{88}Zr liquid sample, we developed a filling station that was remotely operated in the hot cells and dispensed the material in W cans.



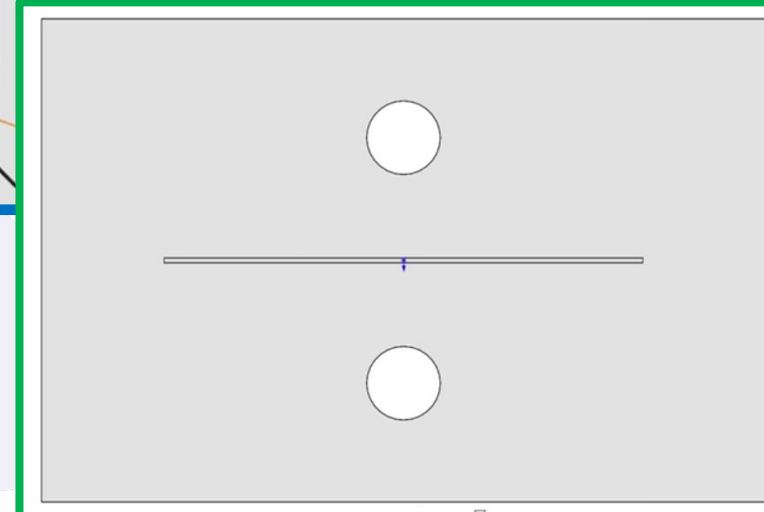
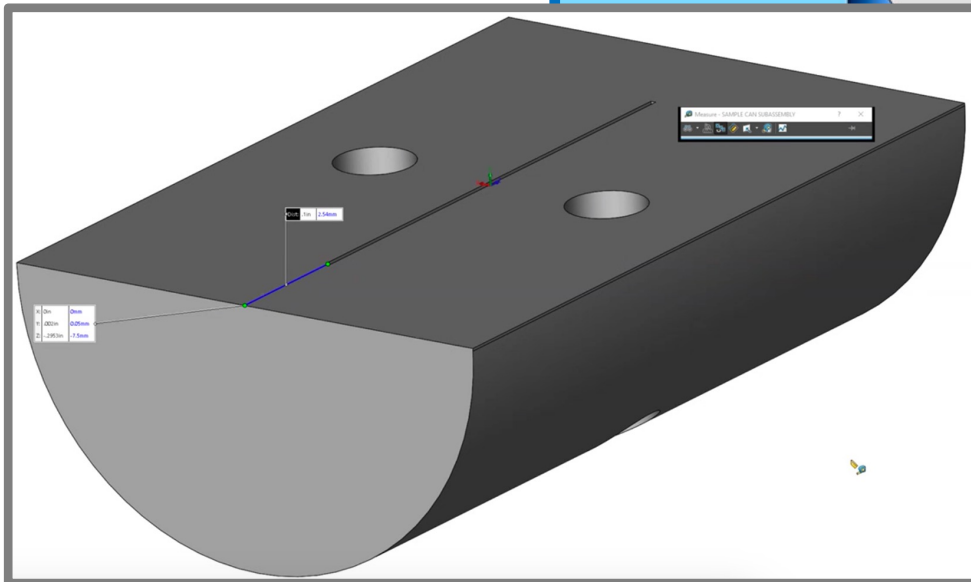
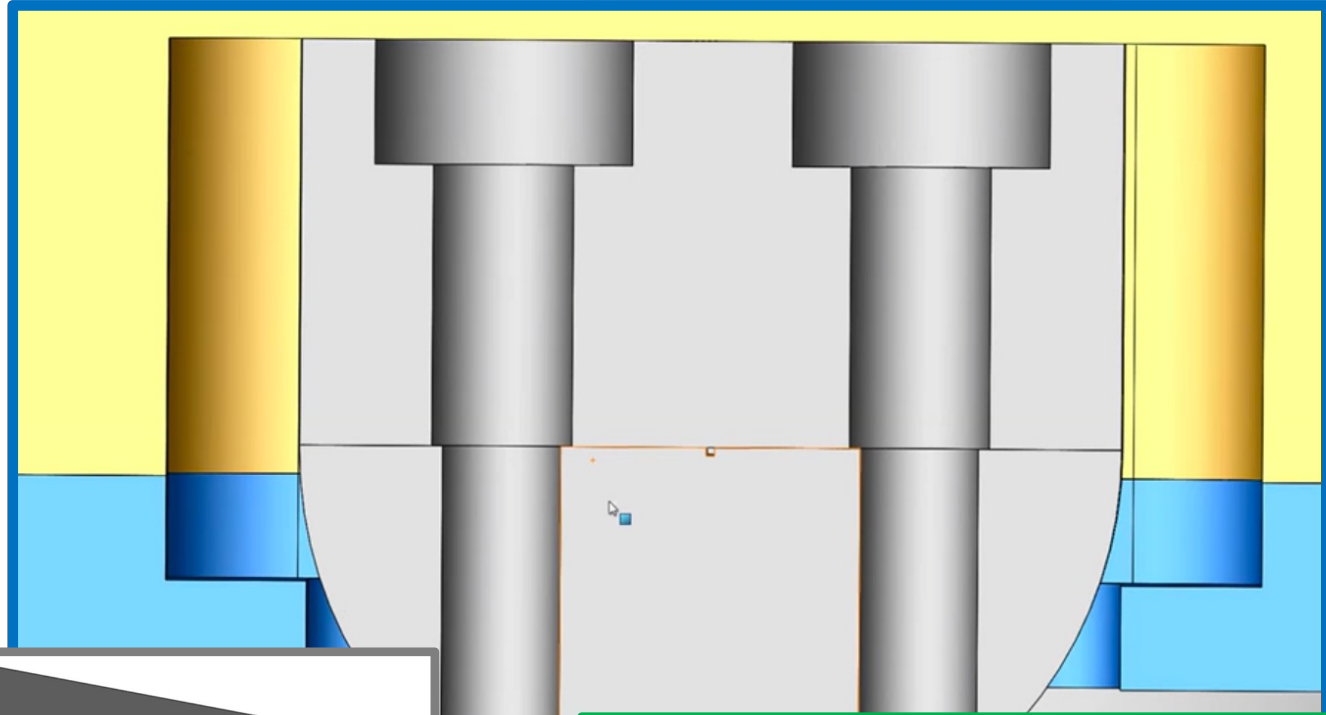
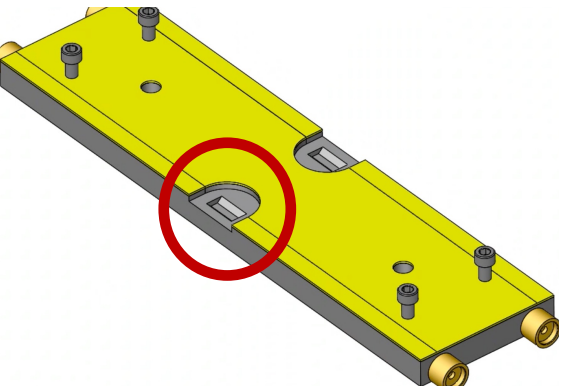
Development of a 0.1 mm collimator : ^{88}Y case

- Need for 0.1 mm-diameter samples: Development of a new 0.1 mm collimator



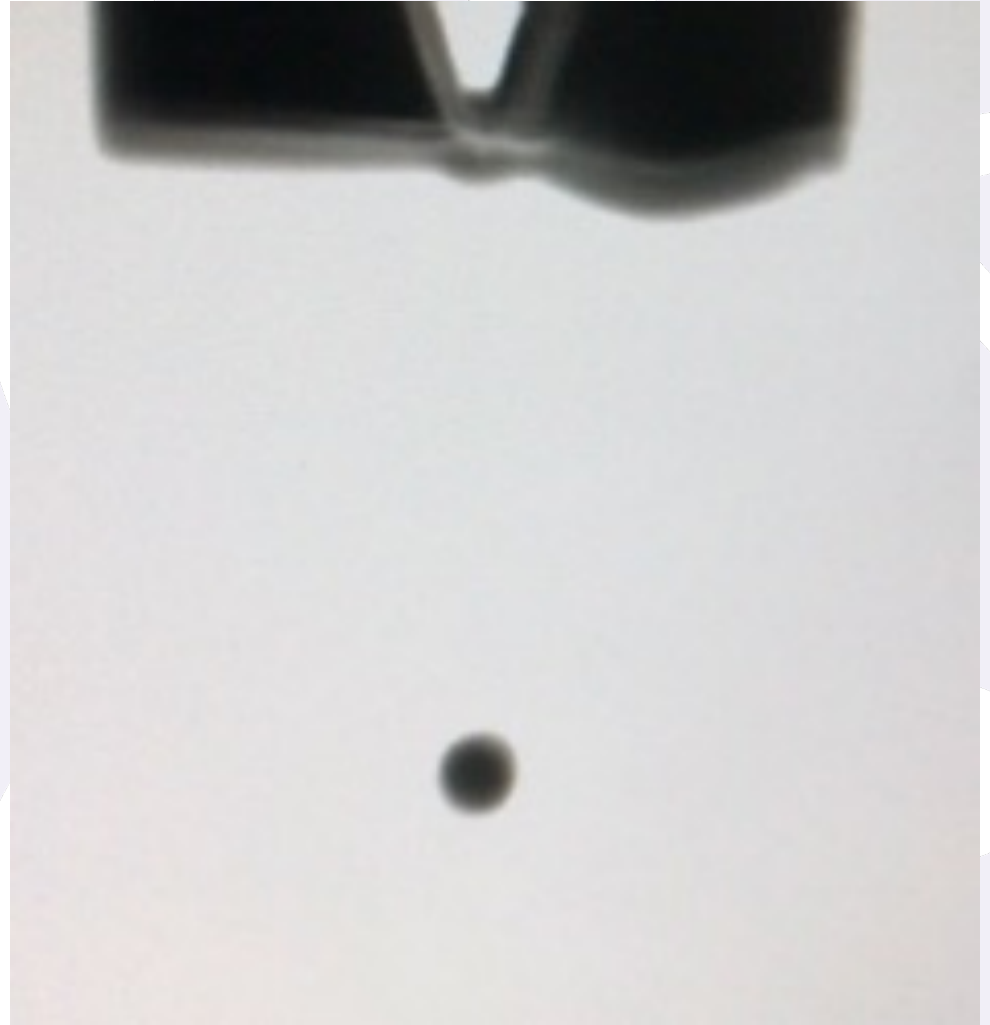
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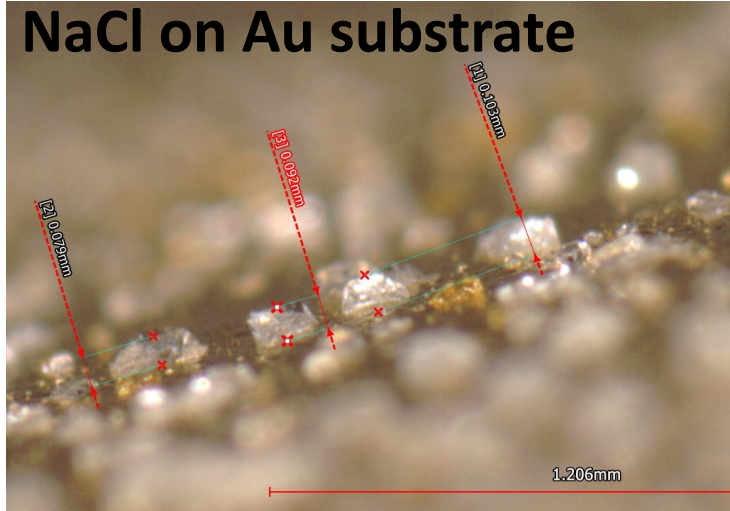
Development of inkjet printing

- Inkjet printing of radioactive samples is a possibility we are currently exploring
- This will hopefully allow to print samples with a small diameter (i.e. ^{88}Y)



Development of inkjet printing

- We managed to print NaCl, some Vanadium salts and YOCl.



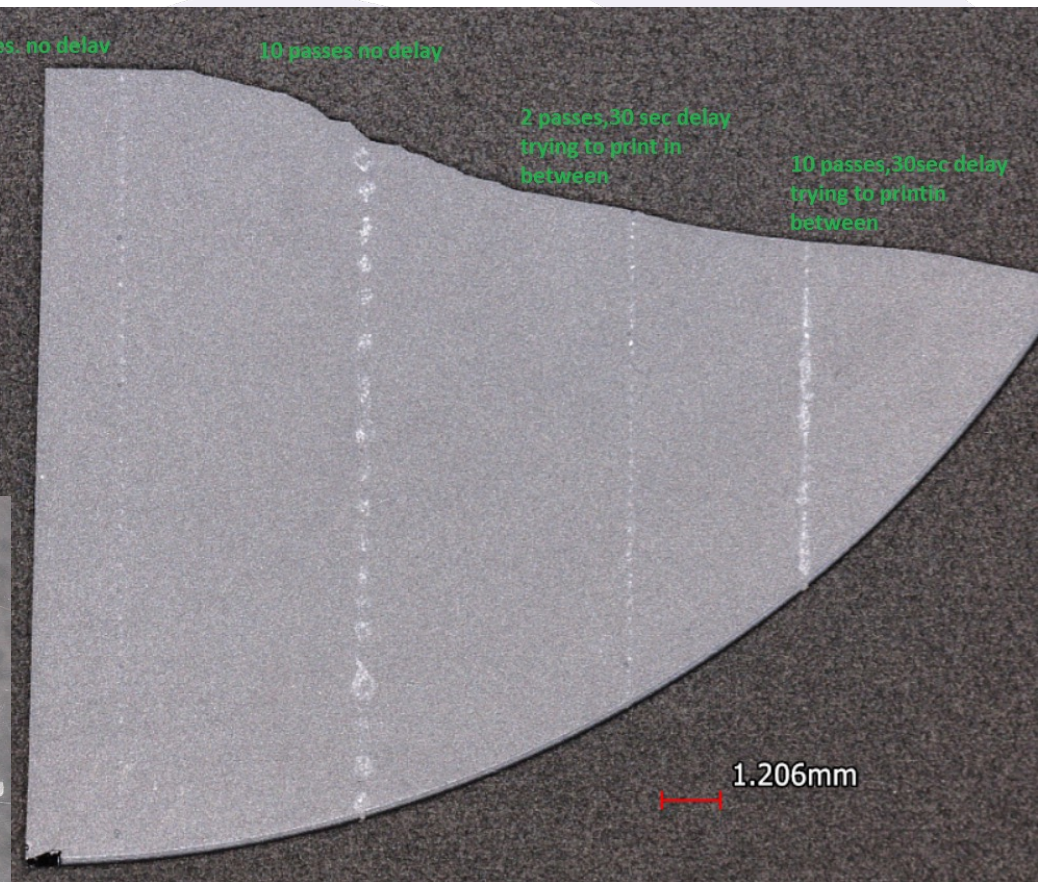
NaCl on silicon substrate; different printer settings

2 passes, no delay

10 passes, no delay

2 passes, 30 sec delay
trying to print in
between

10 passes, 30sec delay
trying to print in
between

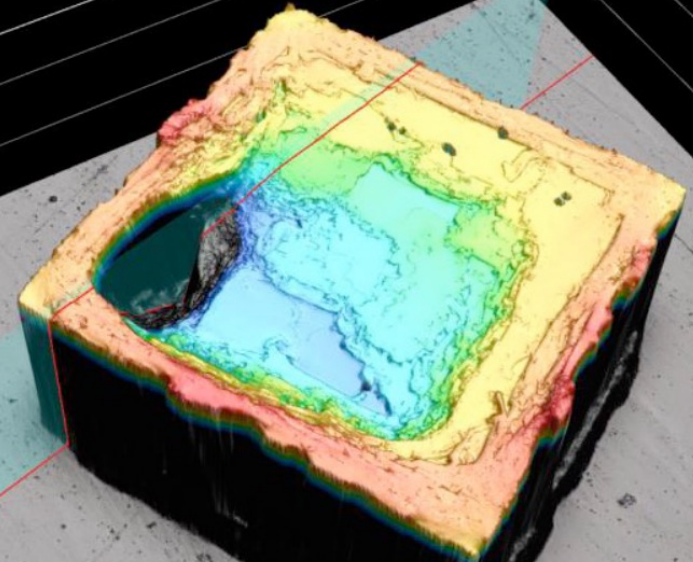
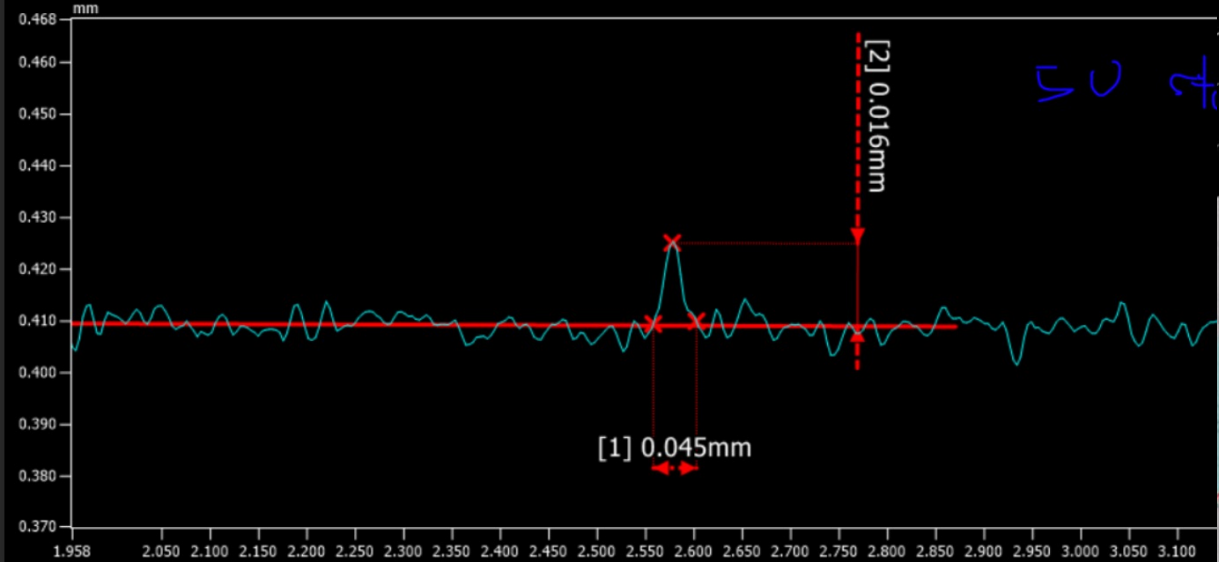
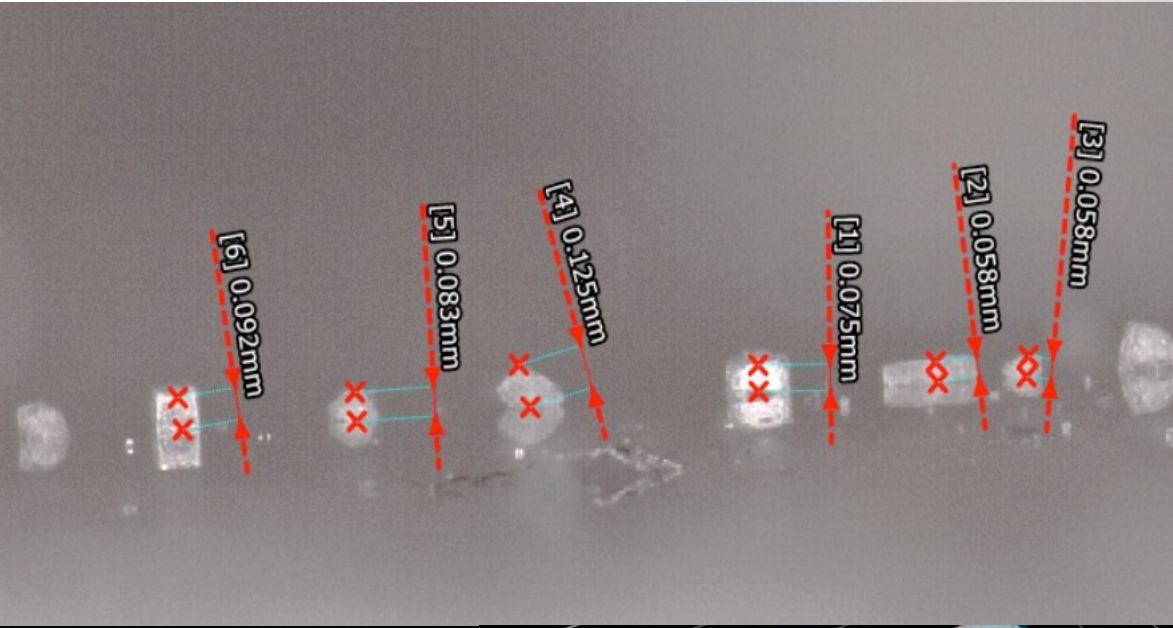
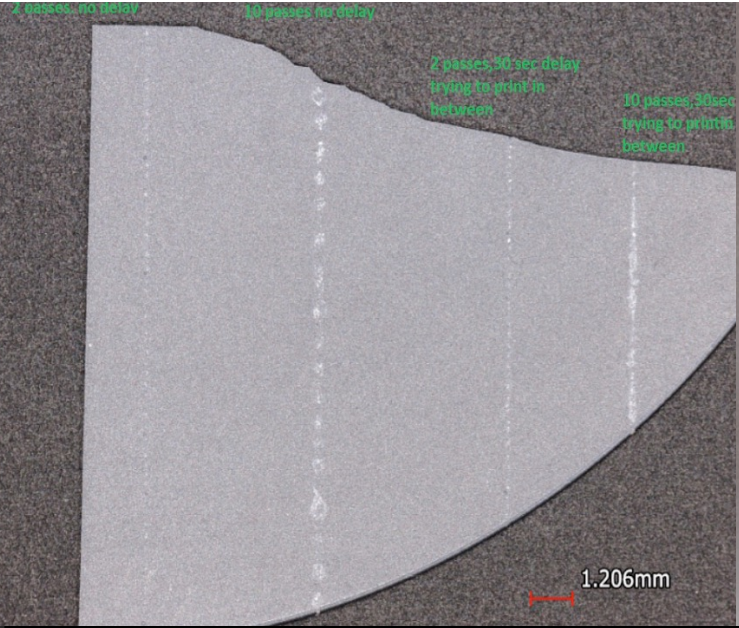


NaCl on plastic substrate



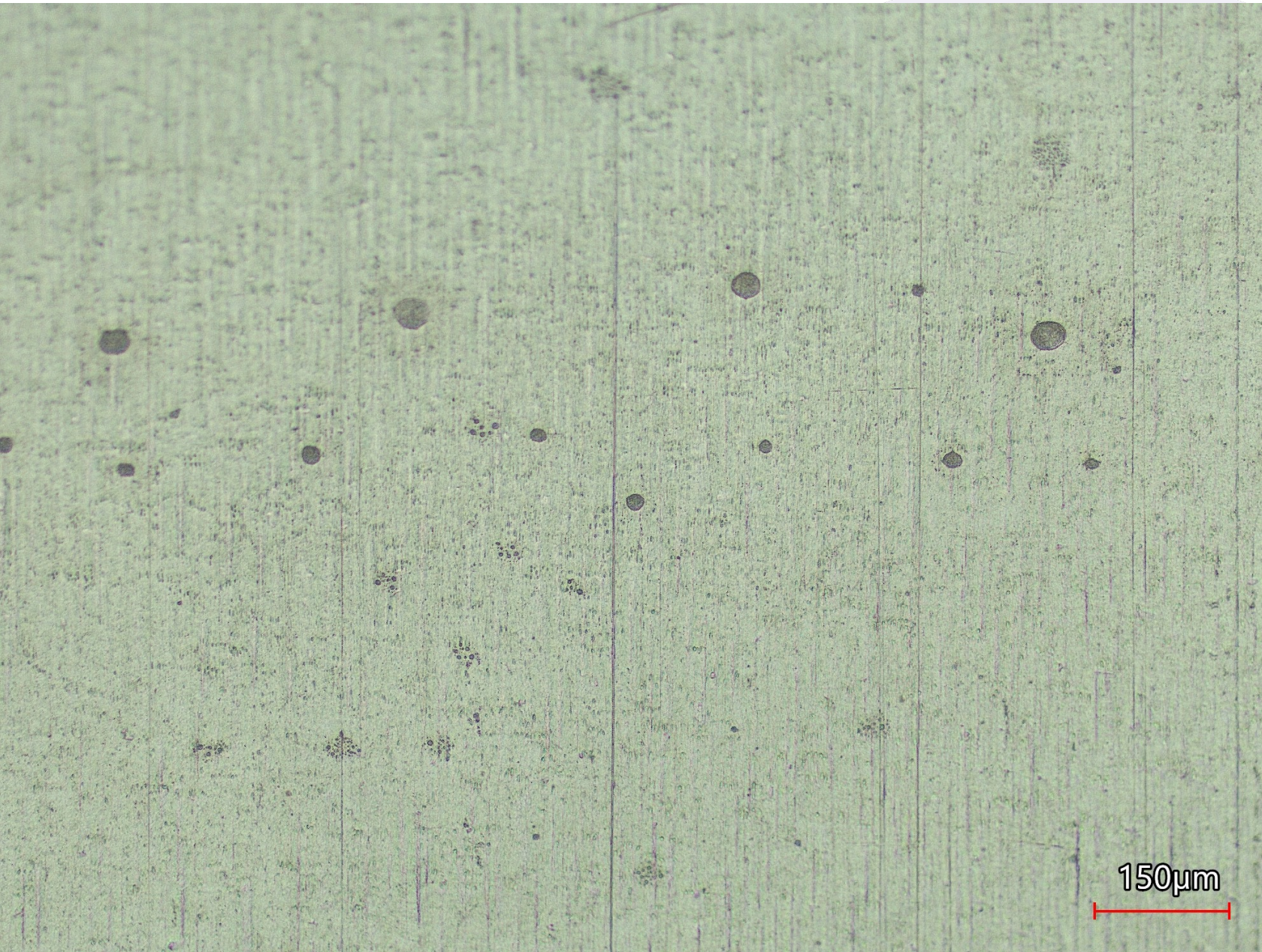
Development of microjet printing

- Inkjet printing of radioactive samples is a possibility that LENZ and DICER are currently exploring



Development of microjet printing

- YOCl ink printed on Zr substrate by Scott Essenmacher



A few future nuclides we would like to study

Nuclide	Half-life
^{88}Y	106.6 days
^{107}Pd	$6.5 \cdot 10^6$ years
^{134}Cs	2.065 years
^{147}Pm	2.62 years
^{152}Eu	13.52 years
^{155}Eu	4.75 years
^{153}Gd	240.4 days
^{163}Ho	4570 years
^{170}Tm	128.6 days
^{185}W	75.1 days
^{186}Re	3.72 days
^{192}Ir	73.8 days
^{193}Pt	50 years

Nuclide	Half-life
^3H	12.3 years
^{171}Tm	1.92 years
^{151}Sm	90 years
^2H	stable
^{133}Cs	stable
^{40}Ar	stable

*Thank you for
your
attention!*



FIESTA 2024

FISSION EXPERIMENTS AND THEORETICAL ADVANCES
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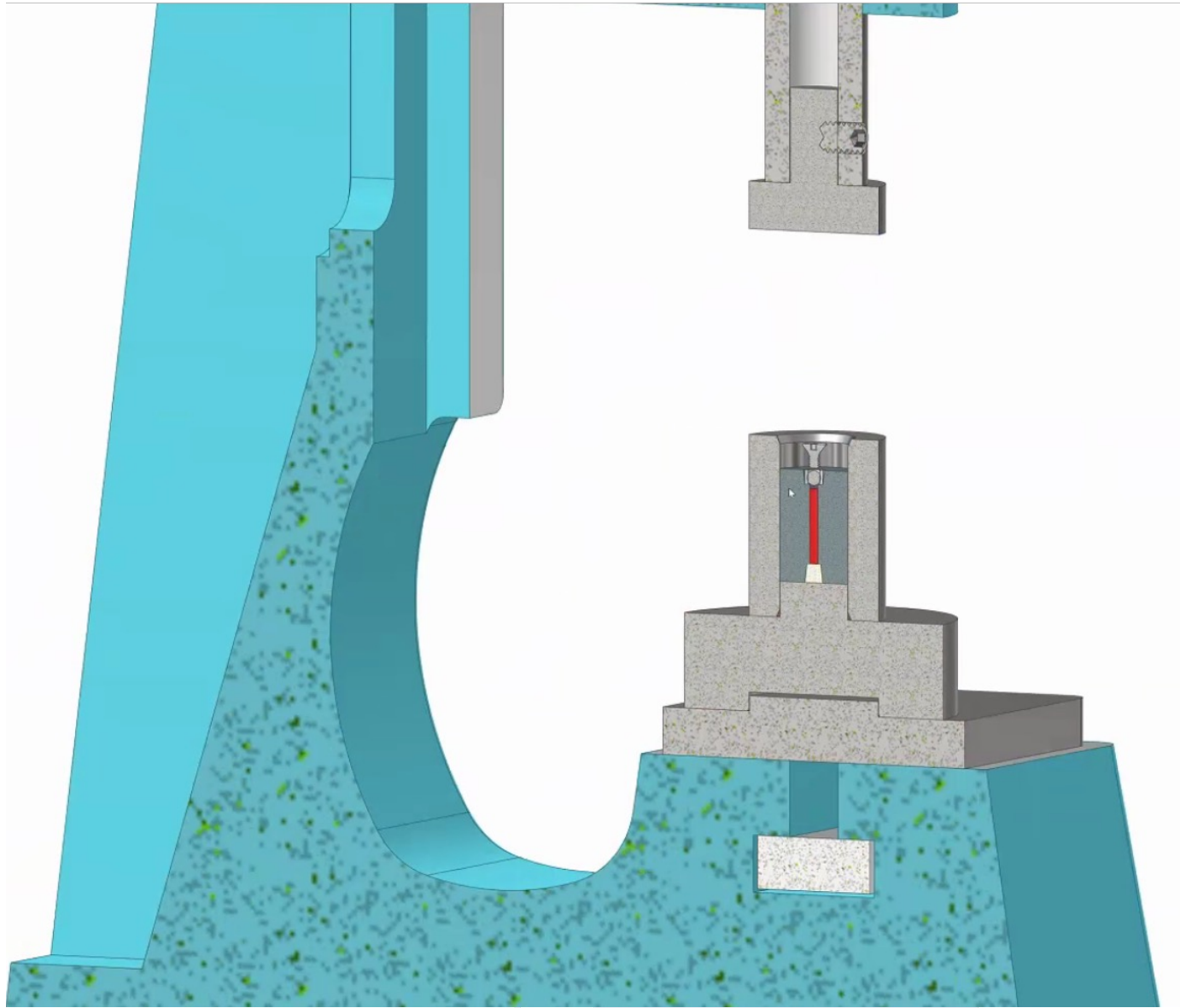
FULLER LODGE ART CENTER
2132 CENTRAL AVE
LOS ALAMOS, NM 87544



Back-up slides



Press that we used to seal the 88Zr sample



The Pb seal we used on the 88Zr sample

- The press deformed the Pb shot

