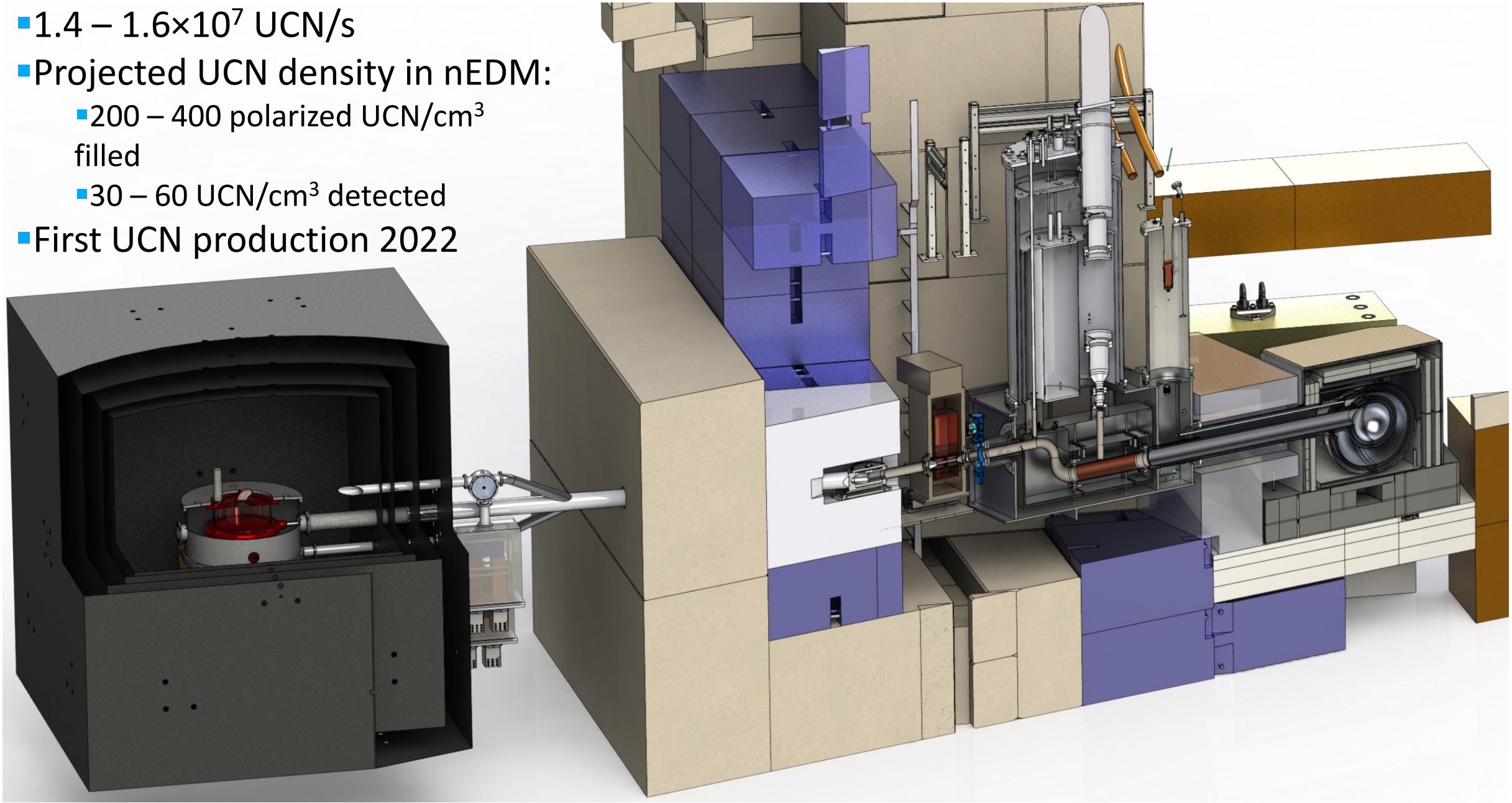
Nickel-Phosphorus Coating Challenges of the TUCAN UCN Source

Russell Mammei

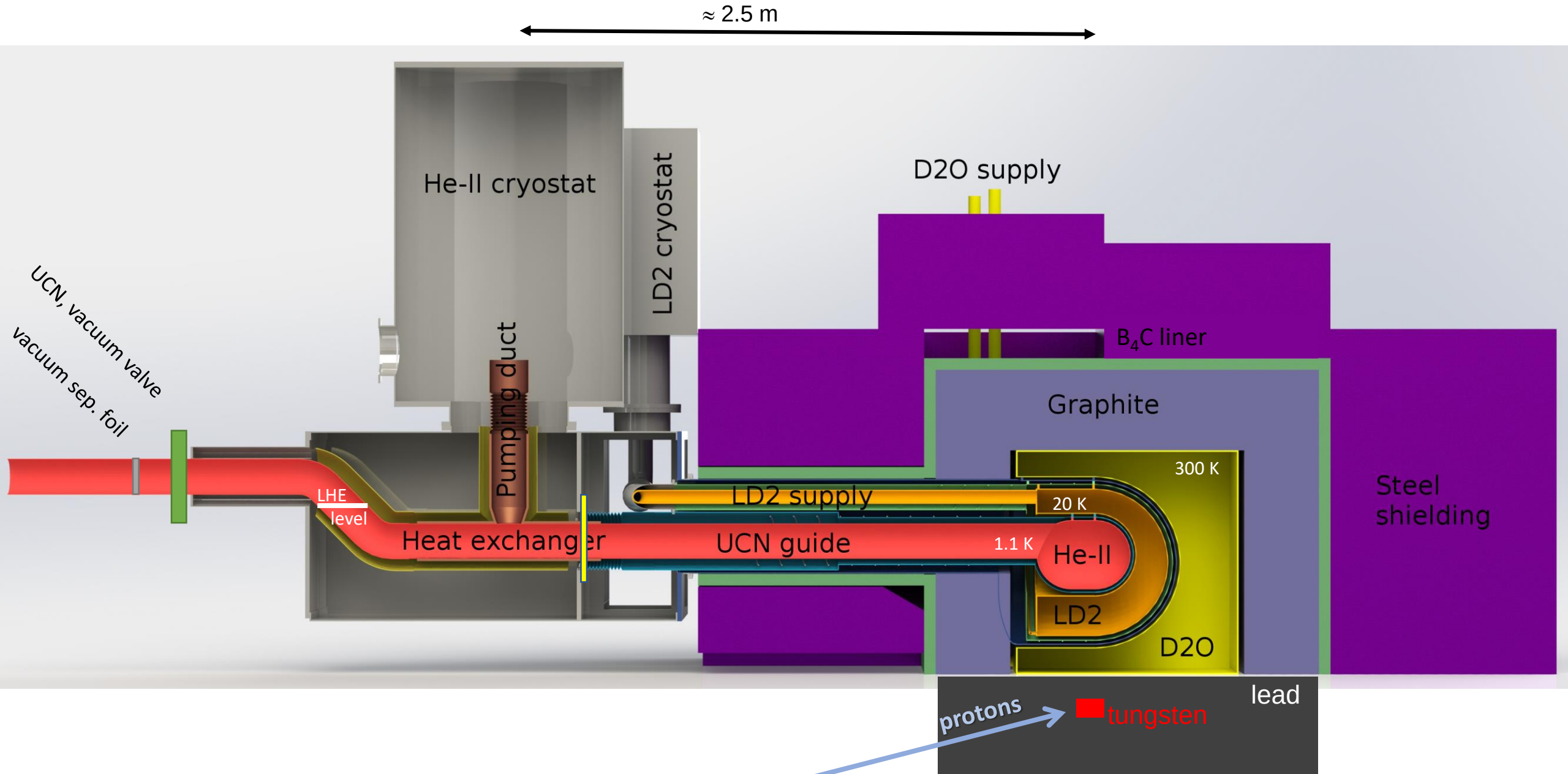
TUCAN Collaboration

TUCAN nEDM and UCN Source Schematic

- 1.4 – 1.6×10^7 UCN/s
- Projected UCN density in nEDM:
  - 200 – 400 polarized UCN/cm^3 filled
  - 30 – 60 UCN/cm^3 detected
- First UCN production 2022



• Next generation UCN source basics



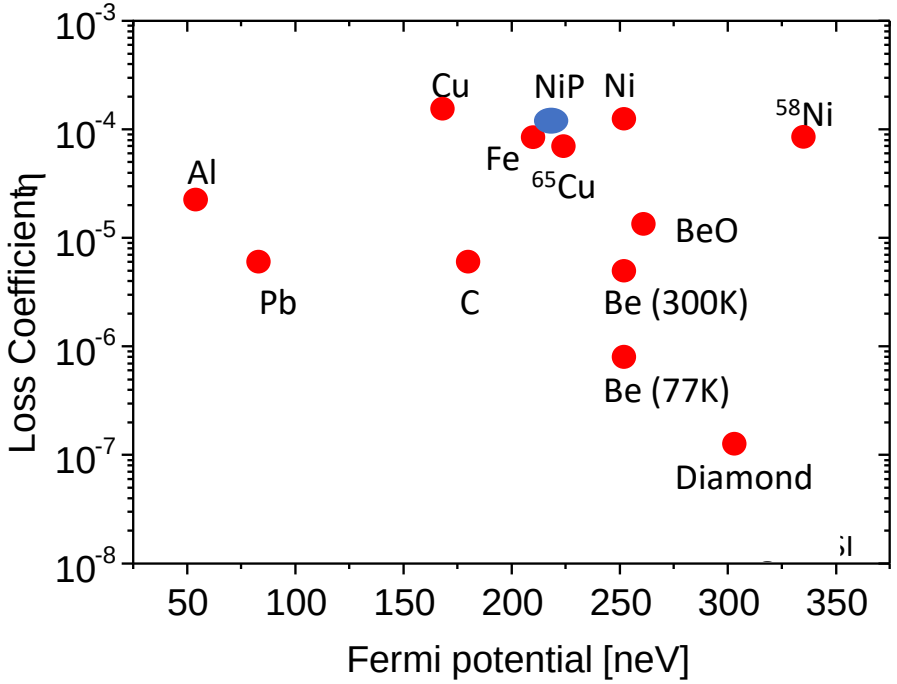
UCN TRANSPORT/STORAGE REFRESHER

Fermi (Material) Potential

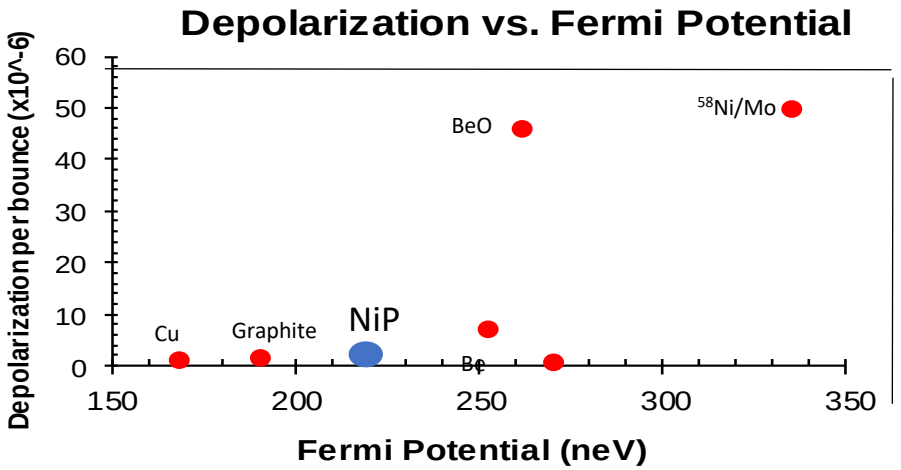
$$V = \frac{2\pi\hbar^2}{m} Nb \qquad \text{UCN flux} \propto (V)^{3/2}$$

UCN Loss Probability

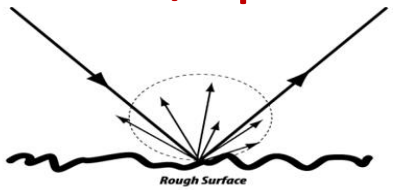
- Neutron absorption
- Inelastic upscattering



Depolarization Probability



Diffuseness /Specular Reflection



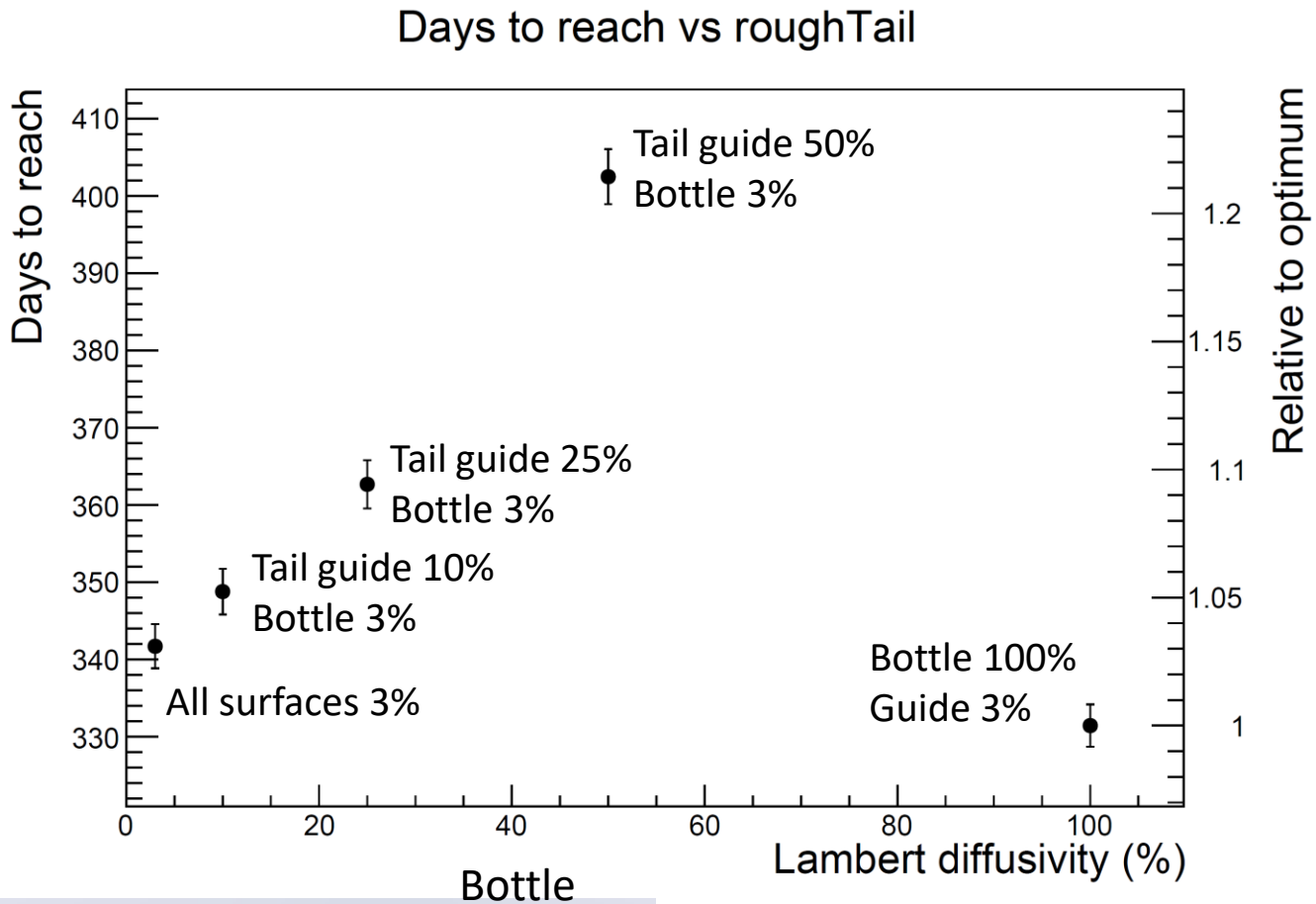
Usually means applying a coating on industrial, machined components

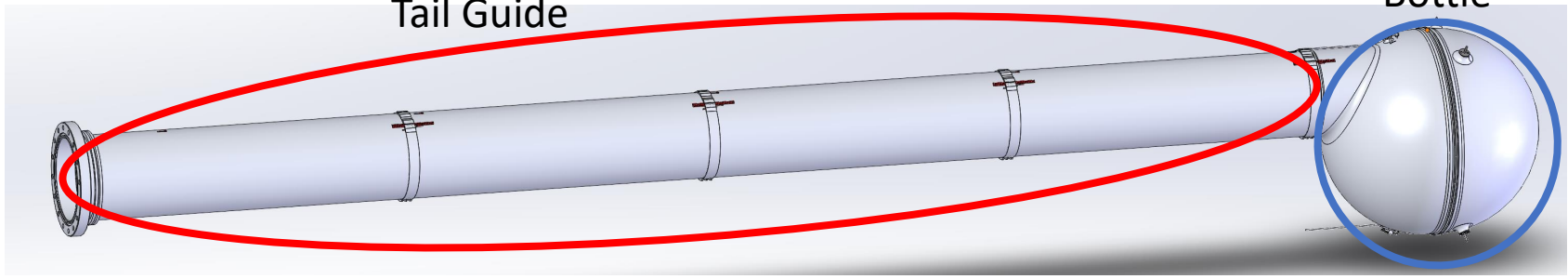
Sensitivity to diffuse reflection in tail

Pentrack UCN simulations of our experiment:

- Metric is Days to Reach a $1\sigma_{stat}$ <10-27 nEDM statistical measurement
- Vary diffuseness using Lambert reflection model

Bottle diffuseness not strong effect
Some Tail Guide diffuseness is okay





Work of Wolfgang Schreyer using Pentrack

NiP coating of He-II tail section

The electroless NiP deposition process requires control of the bath temperature (~80degC) and that the solution circulates over the surfaces to be coated

Challenges:

Aluminum (requires a Zincate or Copper preplating)
2.7 m long (requires baths large enough or willingness to use the tail section as the bath)
Closed on one end (requires pumping to get the solution to flow over the surfaces to be coated

Current supplier:
ChemProcessing in IL,USA
(what LANL uses)
Too long---no interest in using the vessel as the bath.

Spoke to 55 places
(R. Mammei /C. Marshall)

July 2020: Dav-tec (MA, USA)
In principle can do it
Closed end biggest concern
->Coat samples

NiP Coating Acceptance Testing Plan

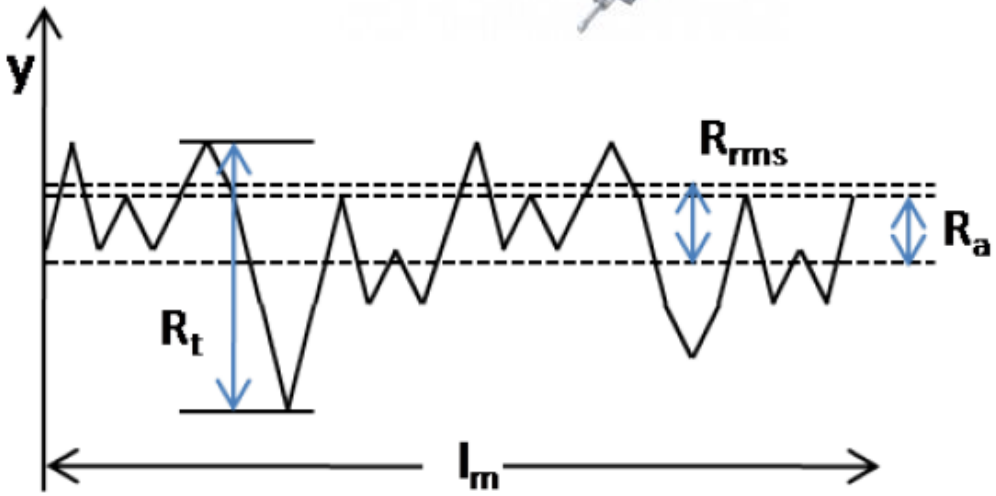
Tests:

- Surface roughness tests
- Adhesion tests:
  - Tape tests (Scotch and Duct tape)
  - LN2 Dunk test (with tape tests afterwards)
- UCN storage lifetime/transport test

Materials:

- Short Tube Samples
- TUCAN UCN Guide
- Mini tail section

We use Mitutoyo SJ-210 stylus surface roughness meter



Ra is the arithmetic average

Polishing company we work with uses the Ra metric in microinch.
Usually our guides are polished to a 2 microinch Ra using the ISO ‘97 standard

1 microinch =~25 nm

1 microinch =~25 nm

Samples

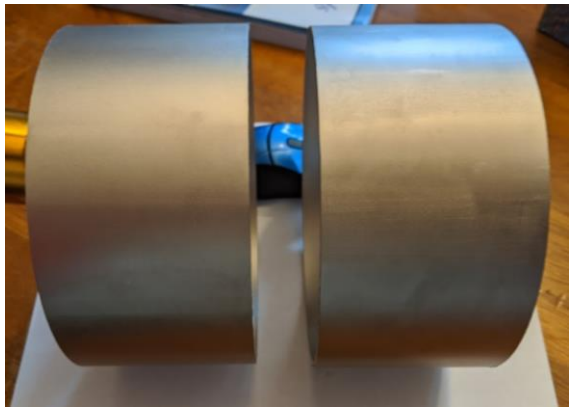
Wolfgang Schreyer has done all the surface roughness measurements

Sent 6” OD ~3” long samples (nominal RA 3 microinch starting roughness)

1st try RA varied along the internal circumference from 20-30 microinch

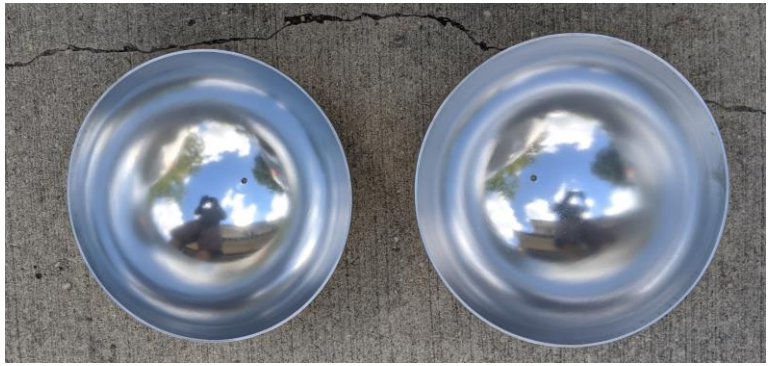
2nd try Ra varied along the internal circumference from 3-5 microinch

(They changed the orientation of the samples in their baths)



Prepared Mini tail section (“bong”)

12” Al hemispheres polished by me, 6” tube ~30” long



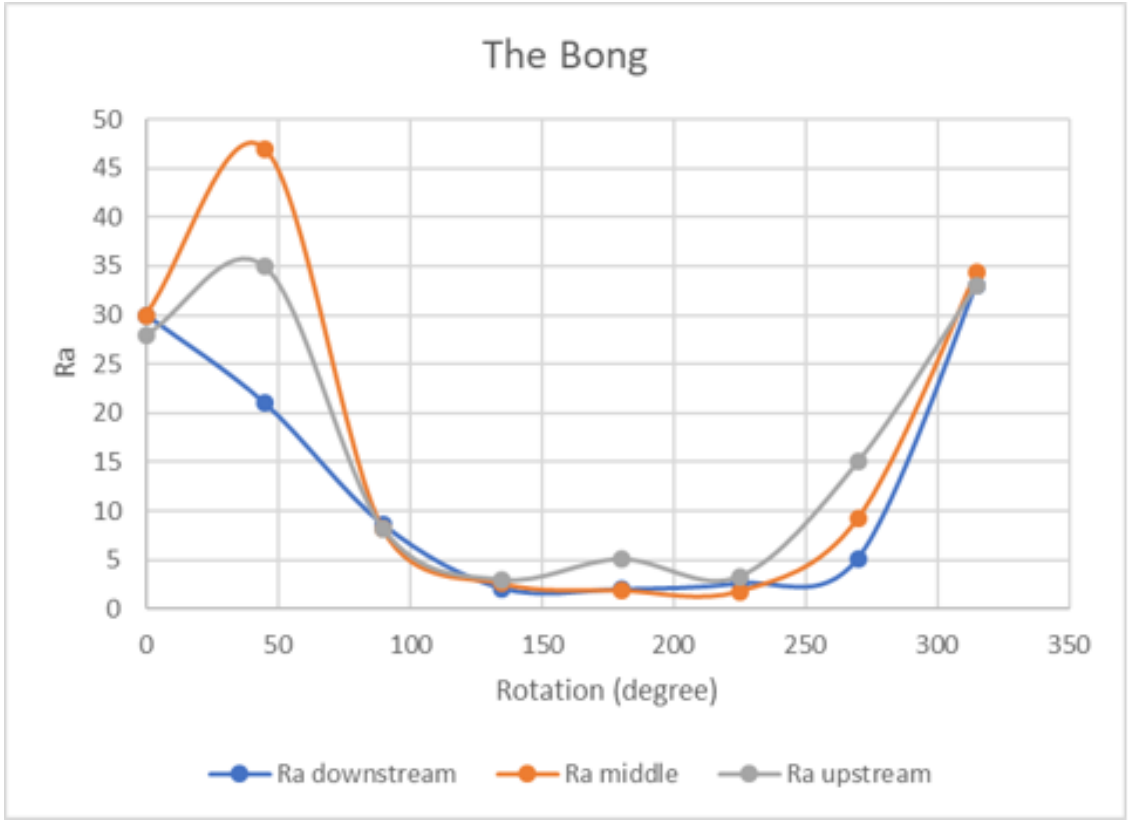
Dav-tec Bong Sample Tests

Work of Woflgang Schreyer

Surface roughness tests (UCN need say)

Adhesion tests:

- Tape tests (Scotch and Duct tape) Passed
- LN2 Dunk test (with tape tests afterwards) Passed



UCN tests of Dav-tec NiP coating at LANL(1)

Goal: Make a relative measurement of Dav-tec coated guide to a Chem Processing coated guide

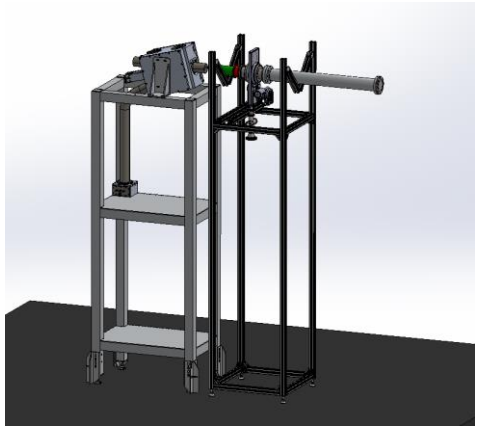
1. To qualify the DavTech coating in general
2. To eliminate any bugs in the measurement for a more important possible tail section test later

Guides:
UGD 201: Dav-tec , 1 m , 4” OD, 10-30 microinch Ra
UGD37: ChemProcessing, 1 m, 4” OD, ~5 microinch Ra

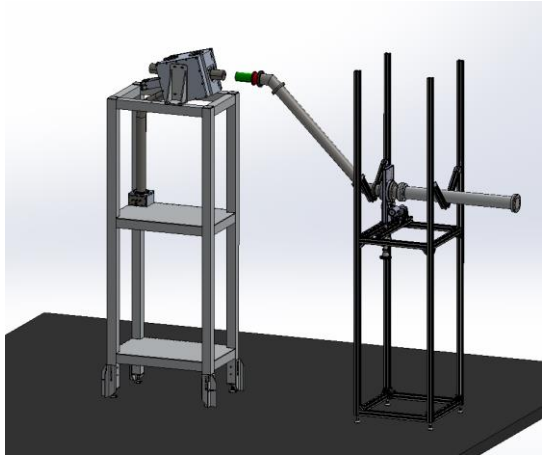
The Covid-19 Pandemic prevented us from going to LANL to make the measurement in Dec of 2020.
-LANL performed the measurement themselves for us:

- **Taufique Hassan** for performed the experiment during 3 night shifts. Thank you!
- **Doug Wong** did the analysis. Thank you!

Test layouts, high position (0-90 neV?)

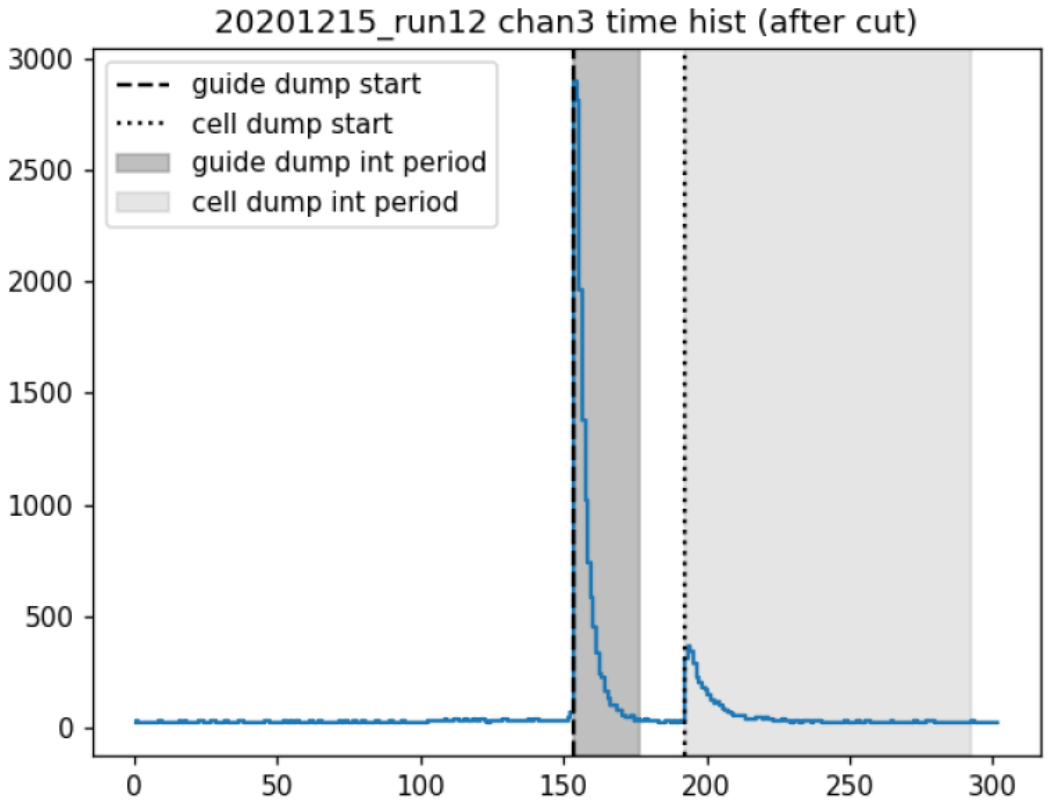


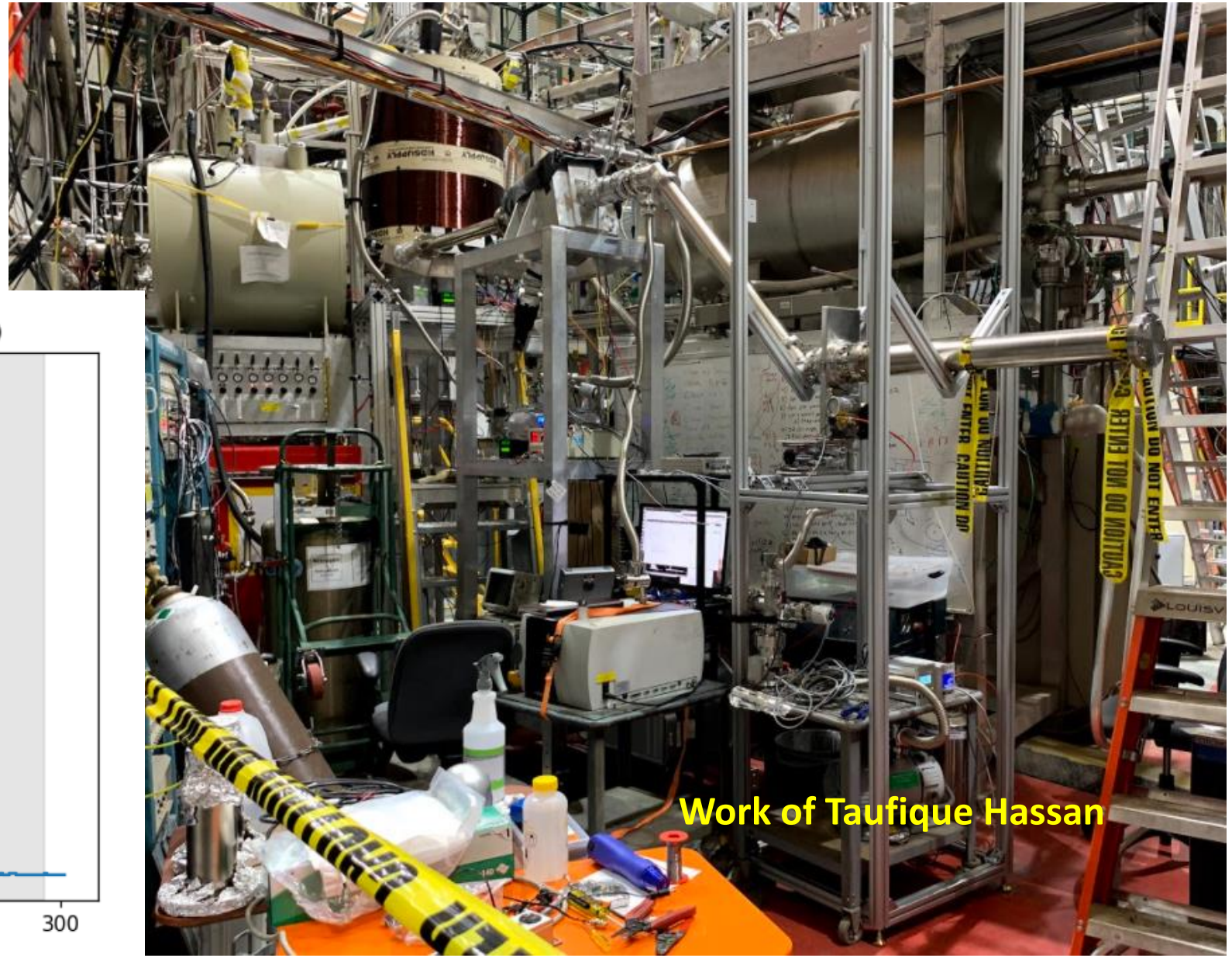
Test layouts, low position (90-180 neV)



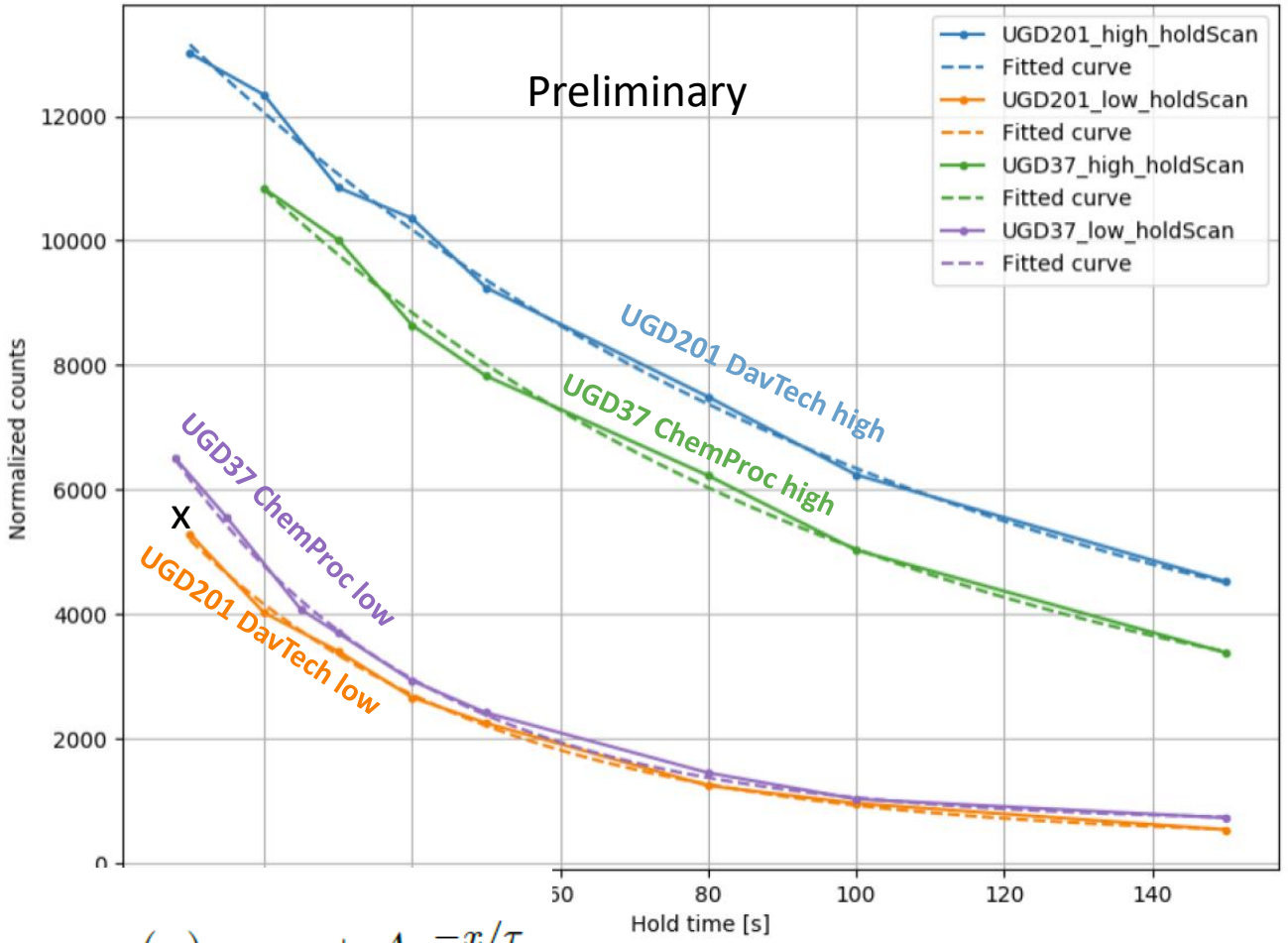
UCN tests of Dav-tec NiP coating at LANL(2)

Example storge lifetime run

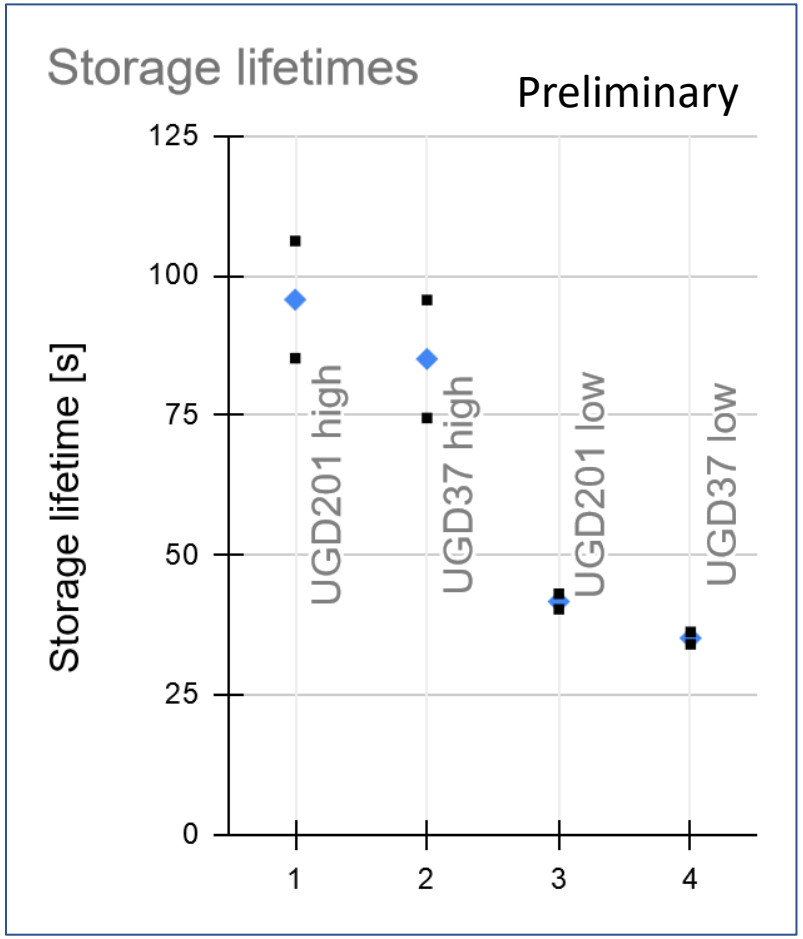




UCN tests of Dav-tec NiP coating at LANL(3)



$$y(x) = y_0 + Ae^{-x/\tau}$$



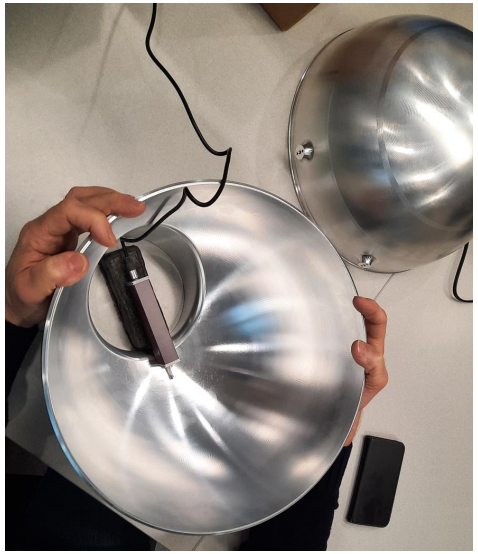
Dav Tech guide tau consistently longer than ChemProcessing:

Some inconsistencies remain to be investigated, but these results gives a high confidence in the performance of the DavTech coating.

Work of Doug Wong

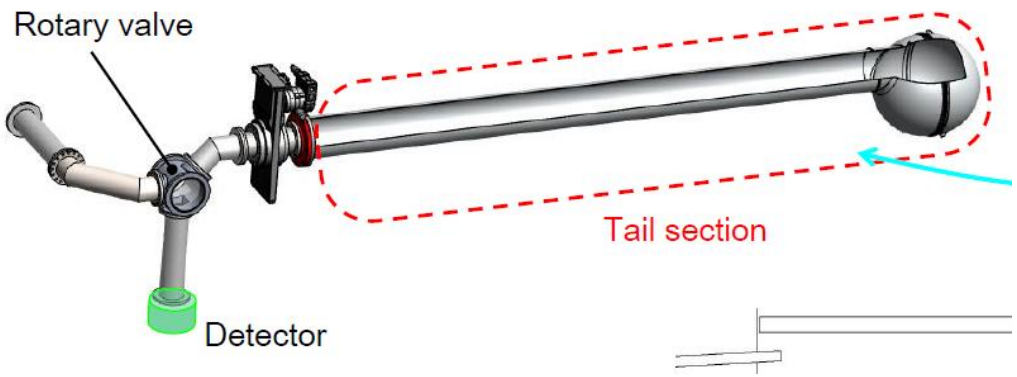
UCN Testing the Tail Section Options

Timeline:
Fabrication of tail section: March ‘21
Coating and Cleaning: April ‘21
Available for testing May ‘21



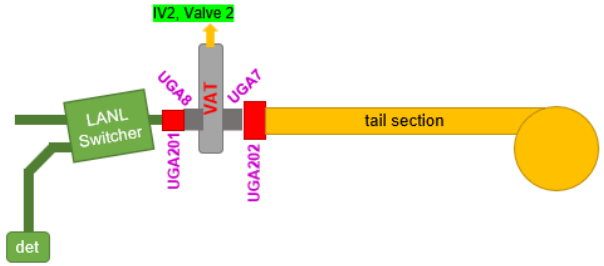
Storage Experiment in J-PARC

Measurement of UCN storage time in the tail section

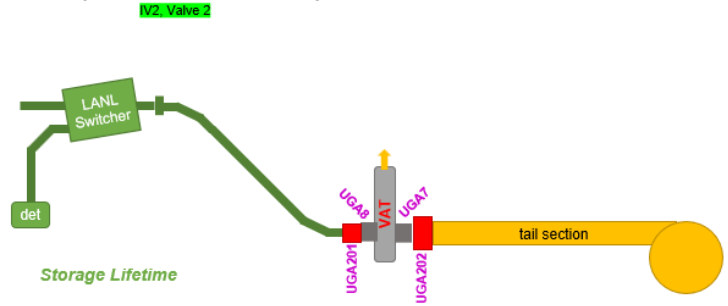


Repeat LANL Storage experiment with tail section

TCN20-010
Tail section, high
Adapter, VAT valve, adapter, tail section



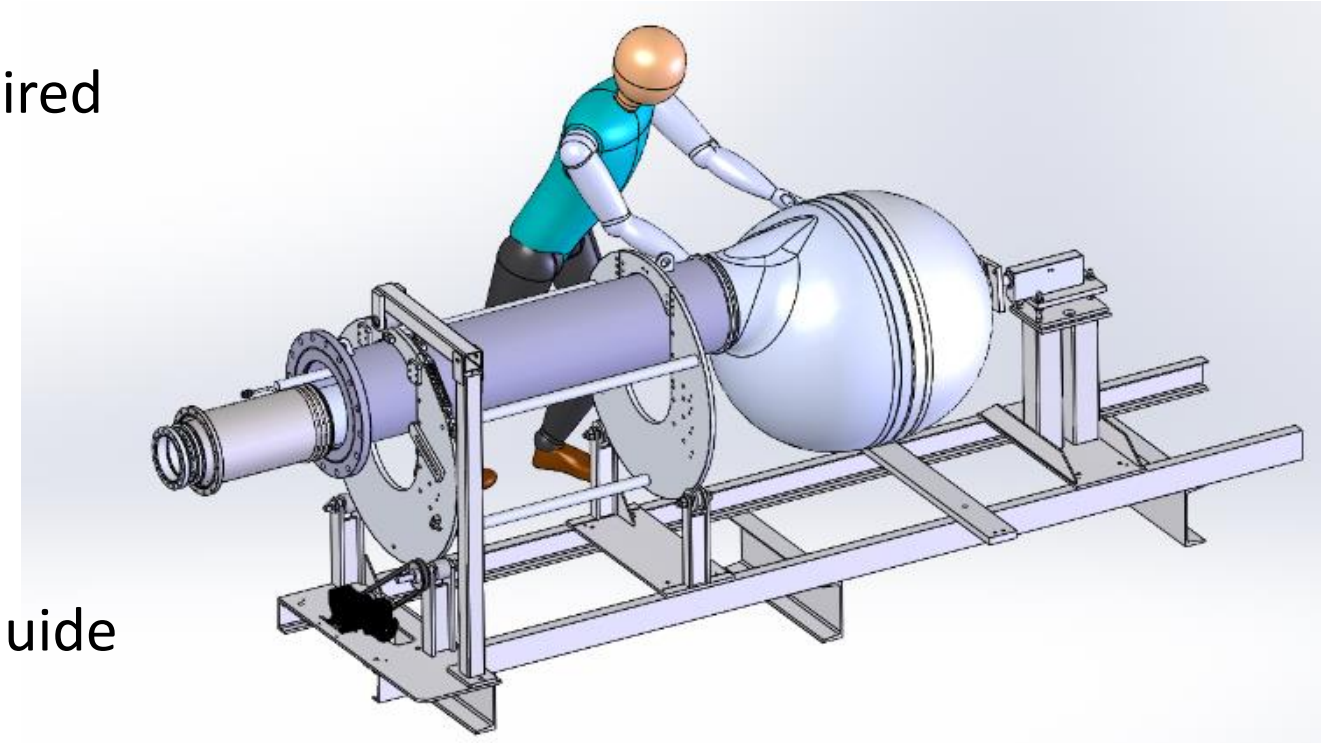
TCN20-110
Tail section, low
Adapter, VAT valve, adapter, tail section



Conclusion

- TUCAN Collaboration's new UCN source expected to begin commissioning in 2022
- NiP coating of UCN source volume required the use of new company: Dav-tec.
- Vetting Dav-tec's NiP
  - Tape tests and LN_2 dunks
  - UCN tests
- UCN Storage time in Dav-tec NiP UCN Guide performed at LANL→ Successful
- Will measure Storage time of the actual UCN source volume later this year.

Tail Assembly Welding Jig



END

He-II vessel (in construction)

- Physics requirements:
  - Low beam heating & neutron absorption
    ➔ Al6061, machined to minimal thickness
  - Good UCN storage & transport
    ➔ Polishing + electroless nickel plating (NiP)
- Engineering requirements:
  - Withstand +/- 1 atm pressure
  - Superfluid leak tight
    ➔ successful weld tests (before and after plating)
  - Accurate temperature measurement
    ➔ optimized coupling of sensors to bottle