Guide-coating facility for the TUCAN EDM experiment

2024 Canadian Association of Physicists Congress

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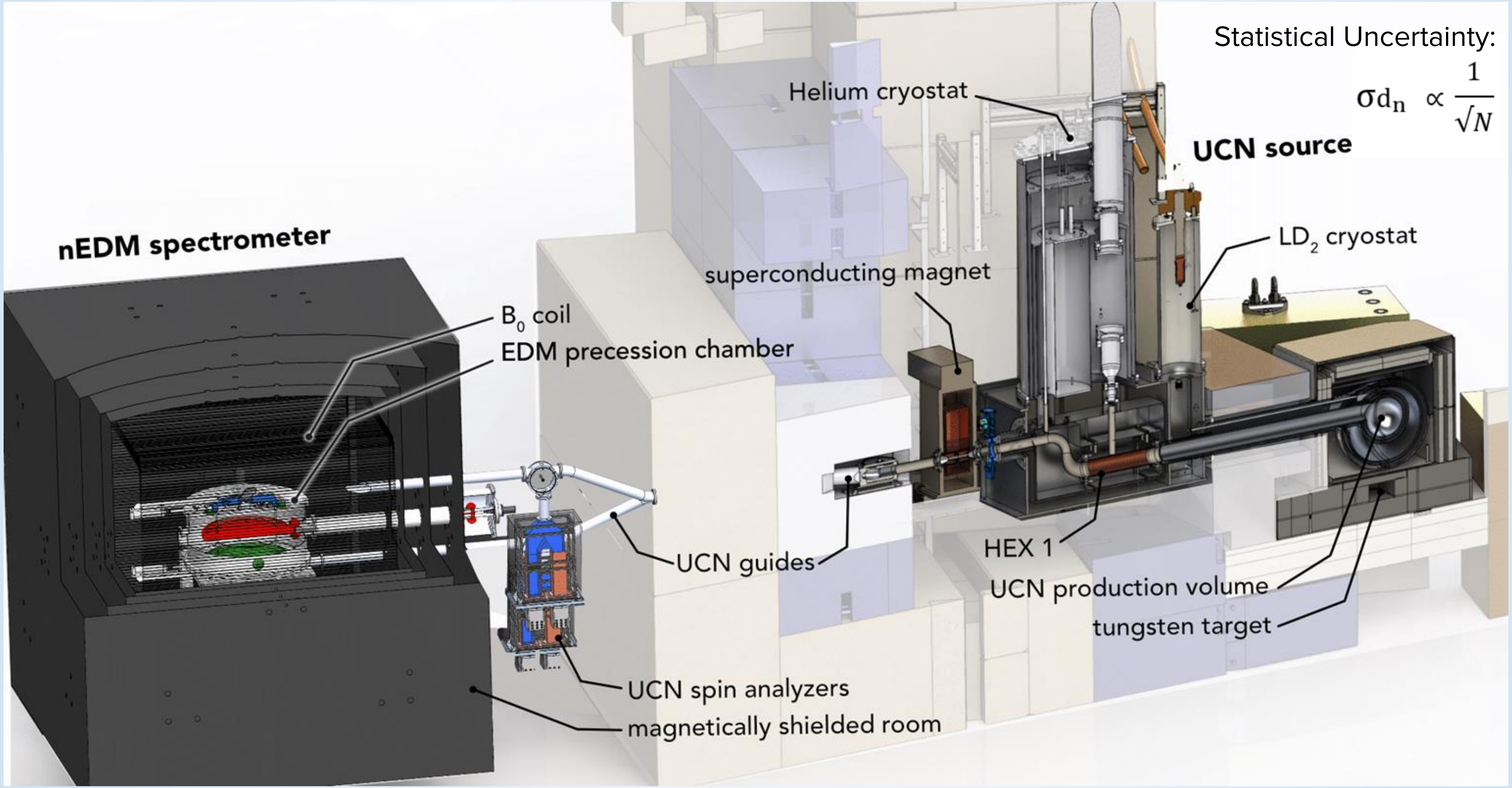
TUCAN EDM experiment



Statistical Uncertainty:

$$\sigma_{d_n} \propto \frac{1}{\sqrt{N}}$$

Ultracold Neutrons (UCN)

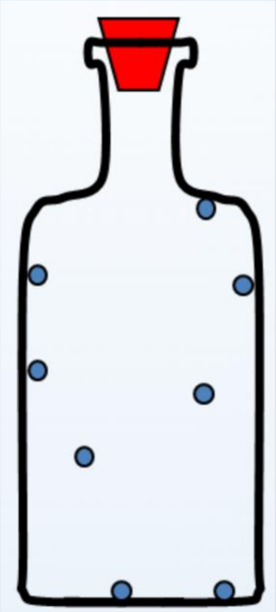
Neutrons that are moving so slowly that they bounce off surfaces and can be bottled.

Ultracold neutrons (UCNs) have very low energies, below 300 neV. At such low energies, they are affected by magnetic, gravitational, and material potentials-strong force, that can be achieved in a laboratory environment.

– $v < 8$ m/s = 30 km/h

– $T < 4$ mK (−273.15 °C)

– K.E. < 300 neV

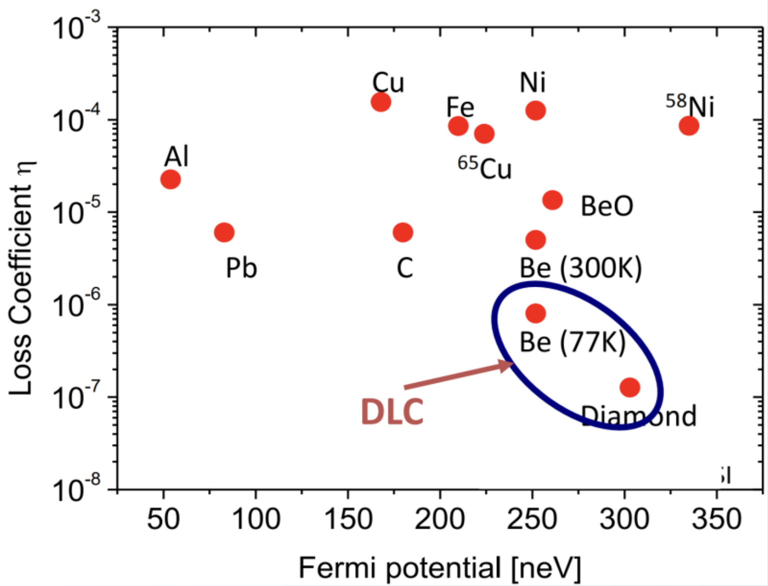


Graph of loss per bounce versus fermi potential

Fermi (Material) Potential

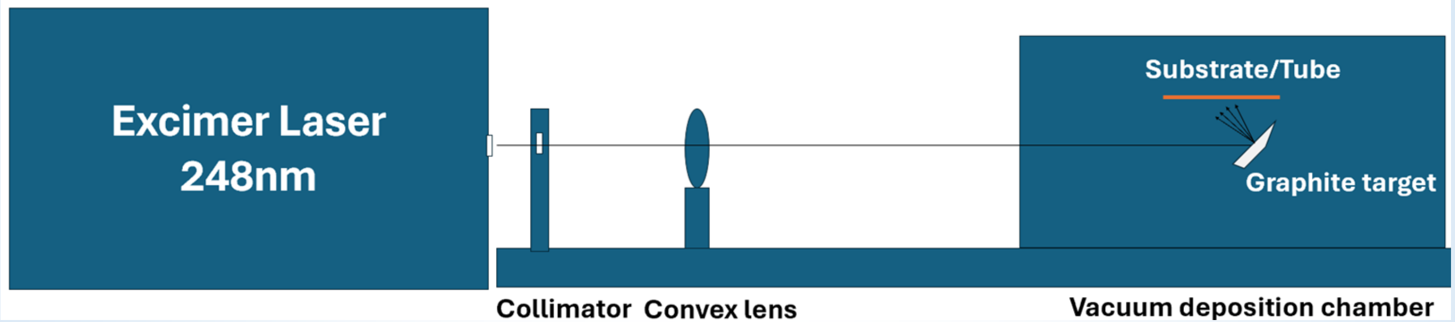
$$V = \frac{2\pi\hbar^2}{m} Nb$$

UCN flux $\propto (V)^{3/2}$

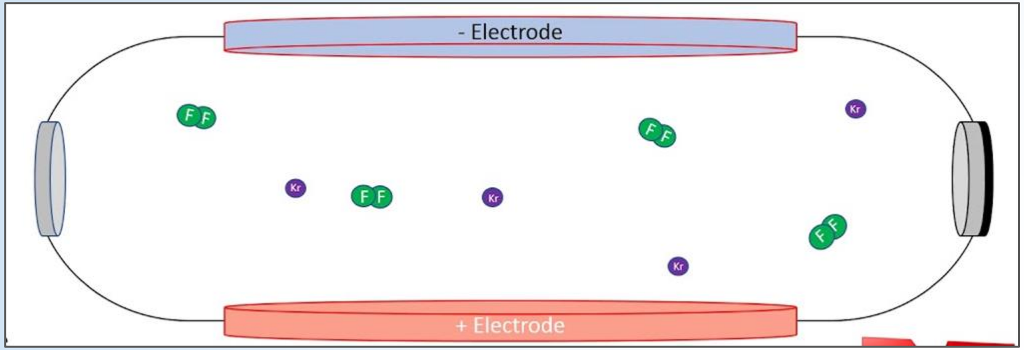


where,
V- Fermi potential
m- mass of the neutron
N- No. density of nuclei of material (no. ofnnuclei/unit vol.)
b- scattering length (strength of interaction between neutron & material nuclei
UCN flux- No. of UCNs/unit area/unit time

Pulsed Laser Deposition Facility at University of Winnipeg



Excimer laser 248nm

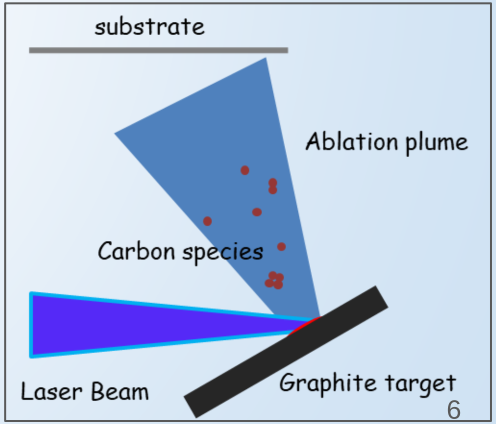


-HV discharge creates meta-stable KrF dimer.

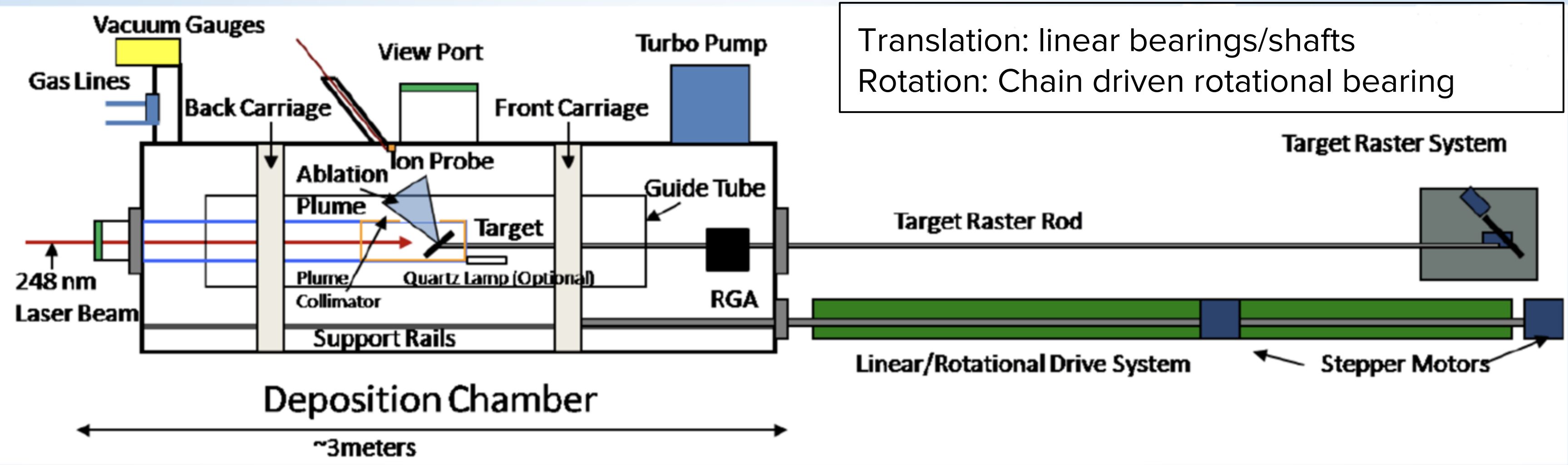
-A KrF dimer relaxes, emitting a UV photon which stimulates the other dimers to emit a UV photo too.

-Produces ~1J/pulse of 248 nm light.

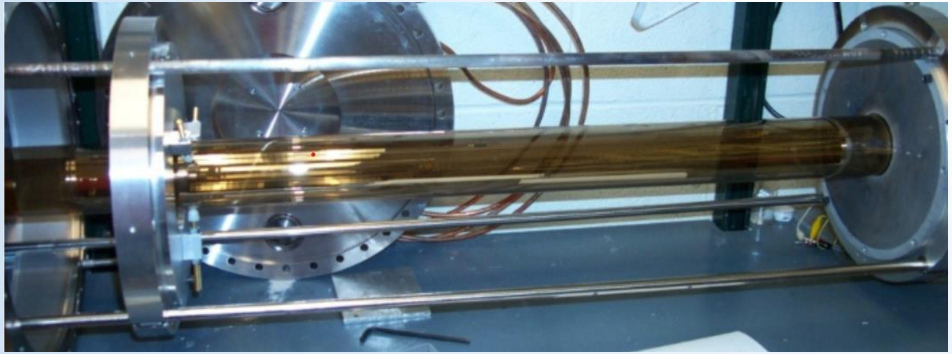
Real carbon plasma plume

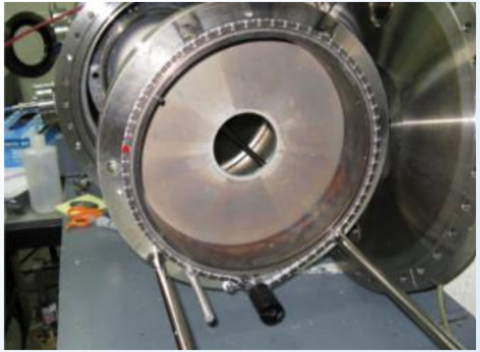


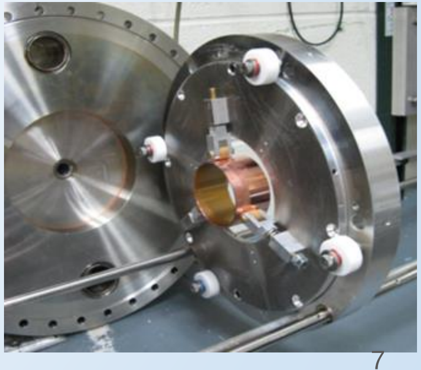
Tube coating chamber



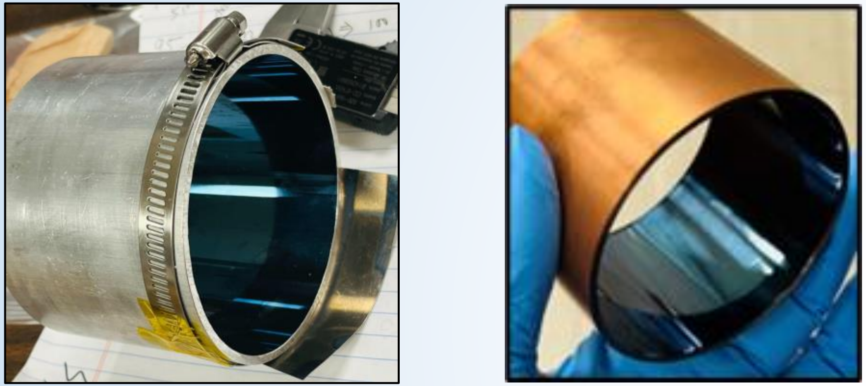
Translation: linear bearings/shafts
Rotation: Chain driven rotational bearing


Carriage system


Front carriage


Back carriage

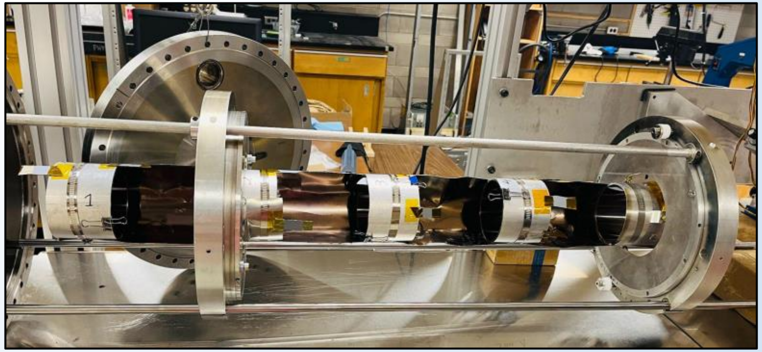
Some DLC coated samples



Aluminum (left) and Copper (right) DLC-coated samples

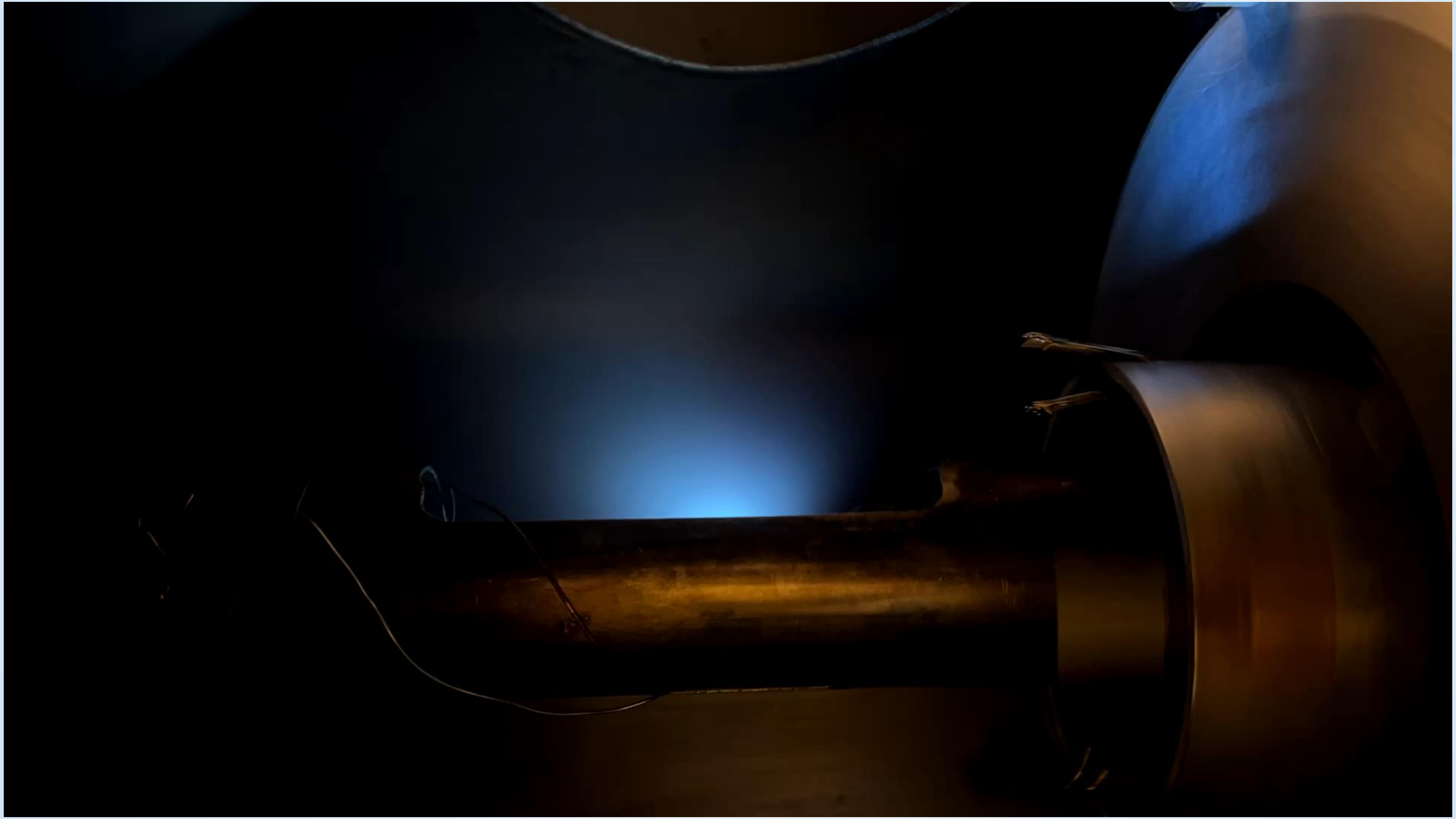
Various parts that can be coated:	
Tubes	~1”-9” inner diameters/ ~1m long
Rods	¼ and ½” outer diameters/ ~1m long
Plates	~5” discs to (30” dia. a year from now)

1 m long DLC coated quartz tube



Train of DLC-coated Al tubes

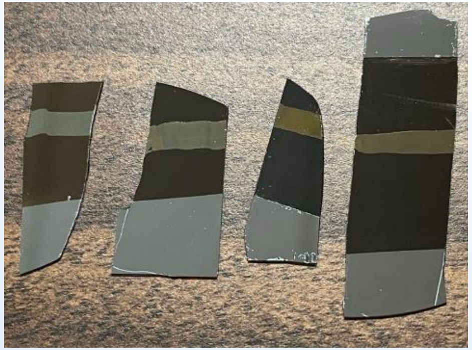
Video of DLC coating- Al tube

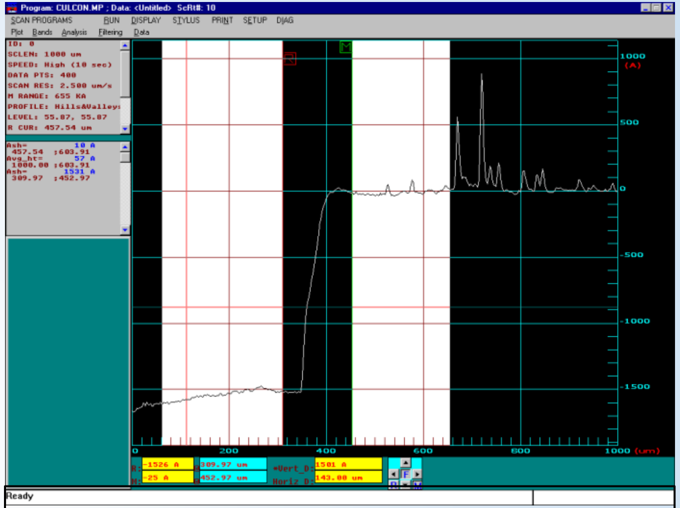


Coating analysis

Film Property	**Surface Science Technique**
Thickness	Profilometry, Ellipsometry, Depth profiles
Density/Fermi Potential	SANS, XPS, XRR
Elemental composition	XPS, SEM-EDS
Surface roughness	AFM, 2D profilometry

Si witness strip along each tube





```
ID: 0
SCLEN: 1000 um
SPEED: High (10 sec)
DATA PTS: 400
SCAN RES: 2.500 um/s
M RANGE: 655 KA
PROFILE: Hills&Valleys
LEVEL: 55.87, 55.87
R CUR: 457.54 um
```

```
Ash=          10 A
 457.54  ;603.91
Avg_ht=       57 A
 1000.00 ;603.91
Ash=        1531 A
 309.97  ;452.97
```

```
R: -1526 A @ 309.97 um   *Vert_D: 1501 A
M: -25 A   @ 452.97 um    Horiz_D: 143.00 um
```

Step height measurement

-We use a stylus profilometer to measure the thickness and surface roughness of the DLC coatings accurately.

-The TUCAN EDM experiment needs DLC films that are > 150 nm.

-Basheer Algohi will be talking XPS analysis on tuesday in the poster session

Status and Future

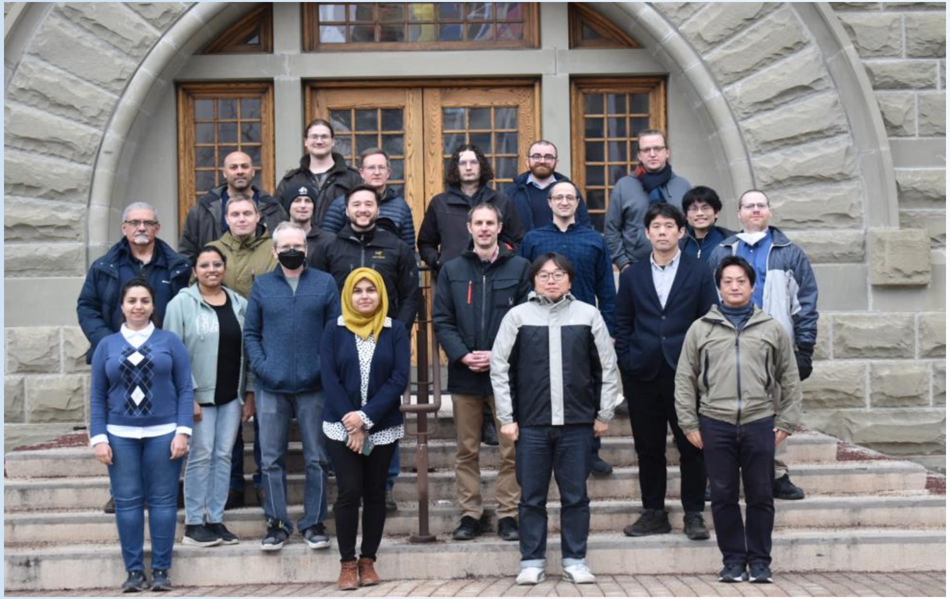
-2024 Summer —Optimize DLC on Aluminum:

Multilayer coating: Chromium (Cr) then DLC- for better adhesion, vary laser energy on target (spot size and laser energy), collimate parts of the ablation plume, etc.

-Fall 2024: produced several 1 m long DLC coated tubes.

-Winter/Spring 2024: Test with UCN at JPARC or TRIUMF.

-Goal to be in UCN Guide production for TRIUMF in 2025.



Collaboration meeting at University of Winnipeg, Feb 2024

Thank you!

Guide Coating Facility is open for Collaboration and providing coatings for your experiment-

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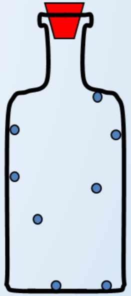
THE UNIVERSITY OF WINNIPEG
University of Manitoba
UNBC UNIVERSITY OF NORTHERN BRITISH COLUMBIA
SFU SIMON FRASER UNIVERSITY
NAGOYA UNIVERSITY
UNIVERSITY OF SASKATCHEWAN
NC STATE UNIVERSITY
TUCAN TRIUMF Ultracold Advanced Neutron Collaboration
KURNS
KEK
RCNP
J-PARC
TRIUMF
JSPS
JST
INNOVATION.CA
CANADA FOUNDATION FOR INNOVATION | FONDATION CANADIENNE POUR L'INNOVATION
NSERC CRSNG

Ultracold Neutron Interactions

UCN ~ kinetic energy < 350 neV / wavelength > 50 nm / velocity < 8 m/s

- Gravity $V_g = mgh \approx 100neV$ per meter
- Weak interaction $n \Rightarrow p + e + \overline{\nu}_e, 782keV$
  - beta decay
- Magnetic interaction $V_m = -\mu \bullet B = \pm 60neV$ per Telsa
  - Changing magnetic field → $F_m = -\nabla V_m = \nabla[\mu \bullet B]$

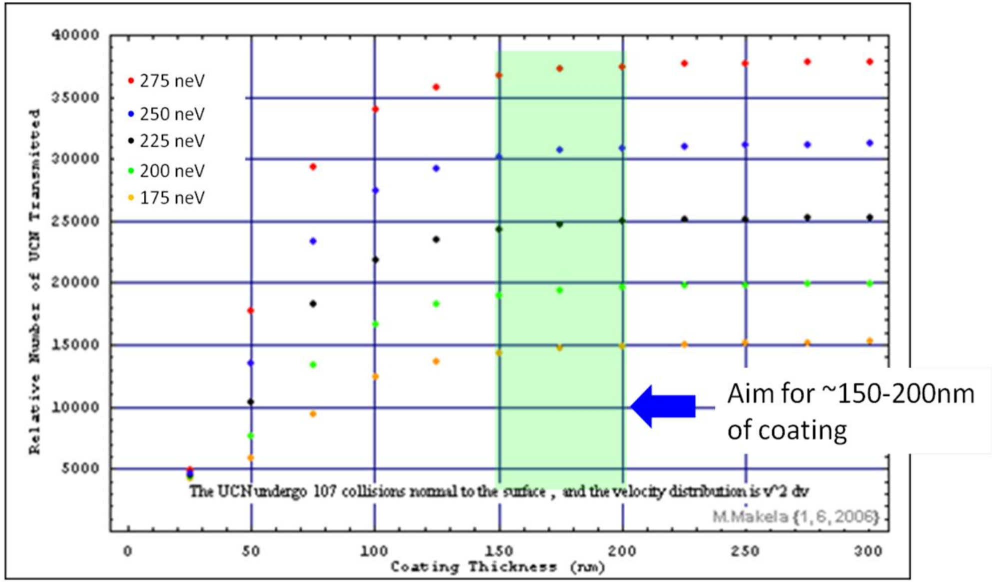
Strong interaction responsible for UCN reflection



Can store/transport UCN on times comparable to their lifetime

Residual gas analyzer

The TUCAN EDM experiment needs DLC films that are > 150 nm.



Aim for ~150-200nm of coating

Figure 3.2: Transmitted UCN versus coating thickness for several different Fermi Potentials. The standard UCN distribution, $v^2 dv$ up to the critical velocity associated with each Fermi Potential, was employed. Figure modified with permission from Mark Makela [111].

From 1st yr quantum mechanics:
UCNs have very low kinetic energy, so they are very sensitive to potential barriers. DLC coating acts like a potential barrier.

DLC thickness greater than 150 nm ensures-
-Neutrons don't tunnel through the barrier (keeping more neutrons contained)

-The potential barrier is high enough to keep the neutrons trapped.