TUCAN

TRIUMF Ultra Cold Advanced Neutron source

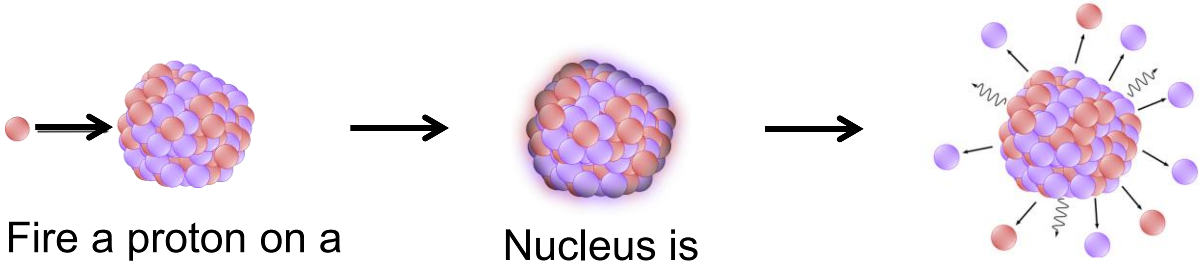
First ultracold neutrons for TUCAN

Alexis Brossard
On behalf of the TUCAN collaboration

Monday, September 22, 2025
Caen

UCN production

Step 1: Kicking (high energy) neutrons out of nucleus.

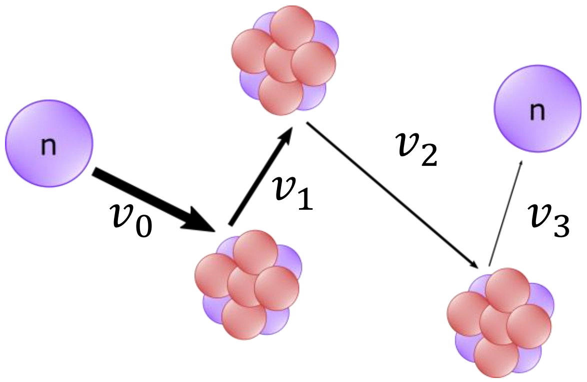


Fire a proton on a high Z target

Nucleus is excited

Nucleus de-excites, releasing MeV neutrons

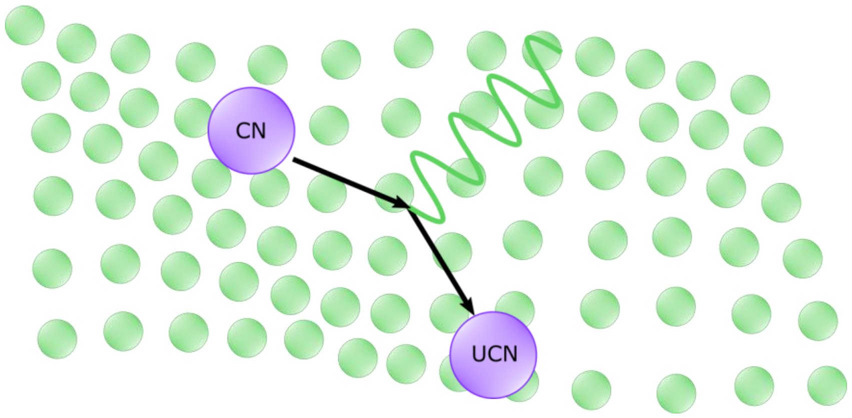
Step 2: Moderation by elastic scattering.

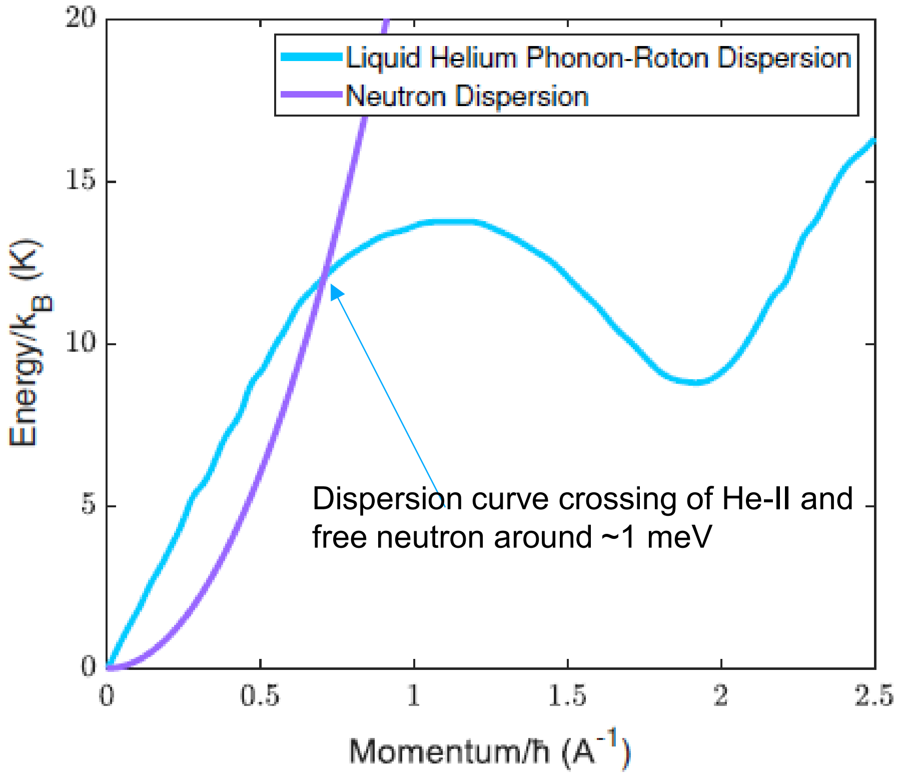


$$v_0 > v_1 > v_2 > v_3$$

Step 3: Superthermal conversion to UCNs

Neutrons with $E \approx 1$ meV can transfer their energy to an excitation of the scattering medium, a phonon.

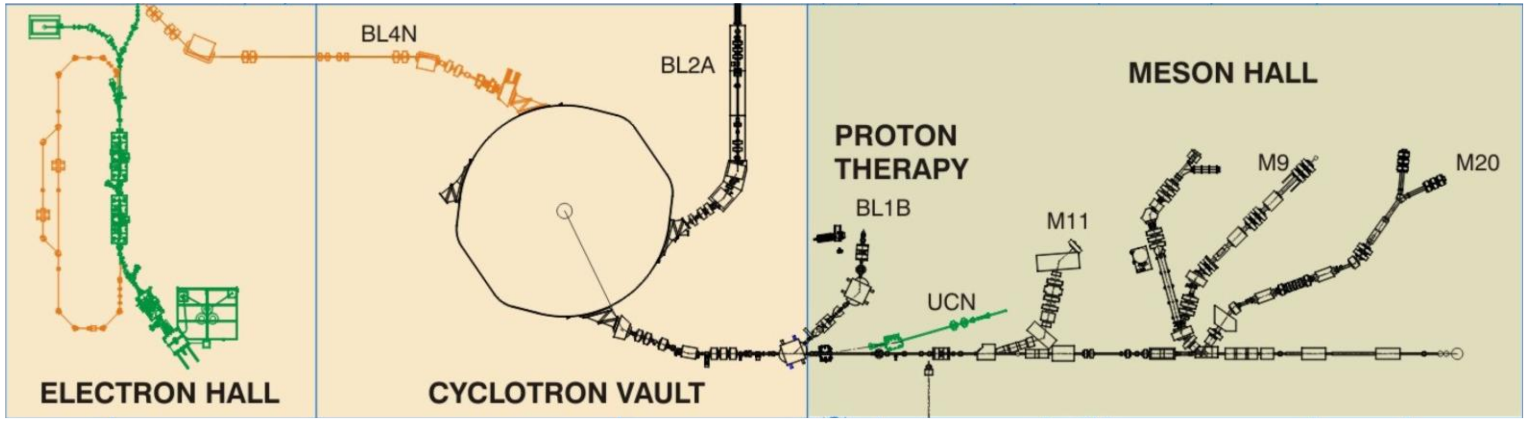


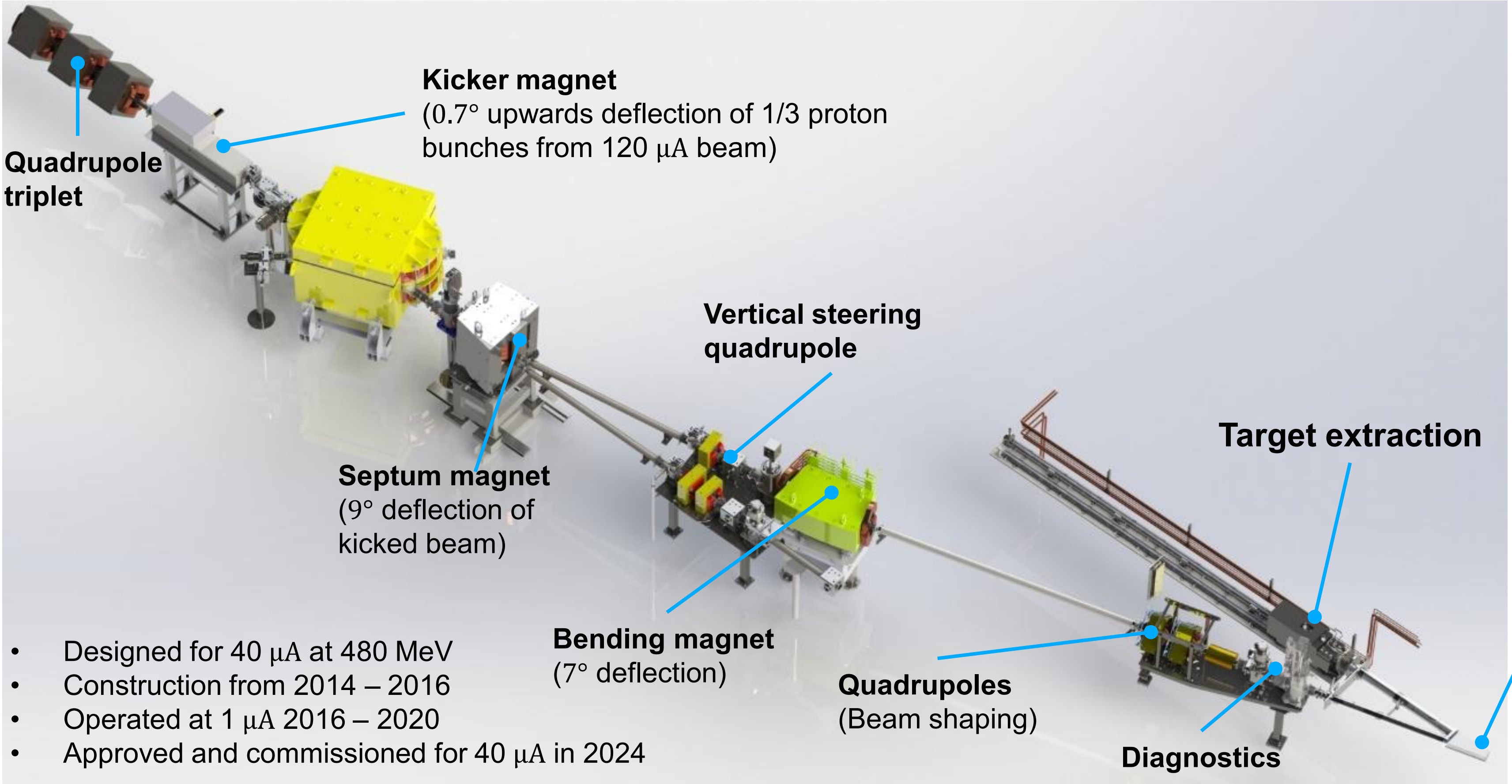


Ultracold Neutrons—Physics and Production, K. KIRCH et al, Nuclear Physics News, Vol. 20, No. 1, 2010, K. KIRCH et al

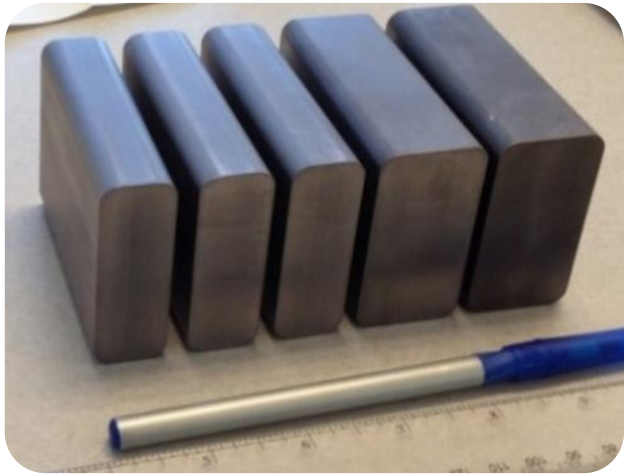
TUCAN
TRIUMF Ultra Cold Advanced Neutron source

Step 1: Kicking (high energy) neutrons out of nucleus

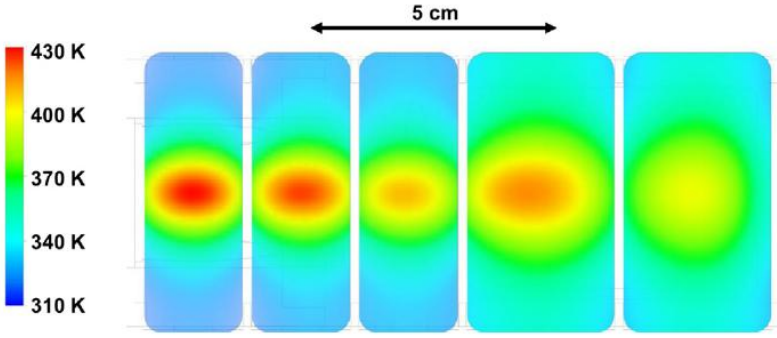




- Designed for 40 μA at 480 MeV
- Construction from 2014 – 2016
- Operated at 1 μA 2016 – 2020
- Approved and commissioned for 40 μA in 2024



Tantalum-clad tungsten target

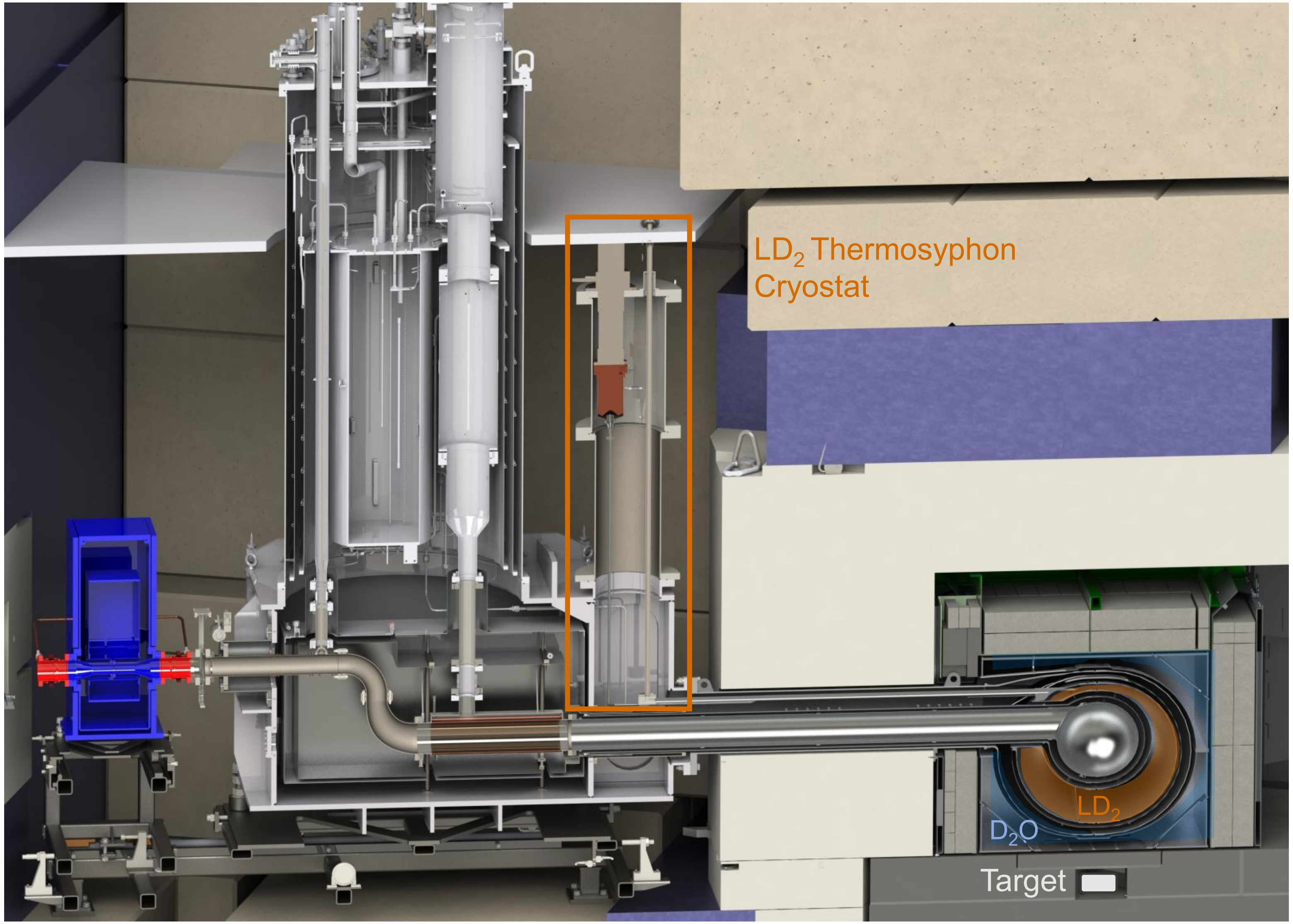


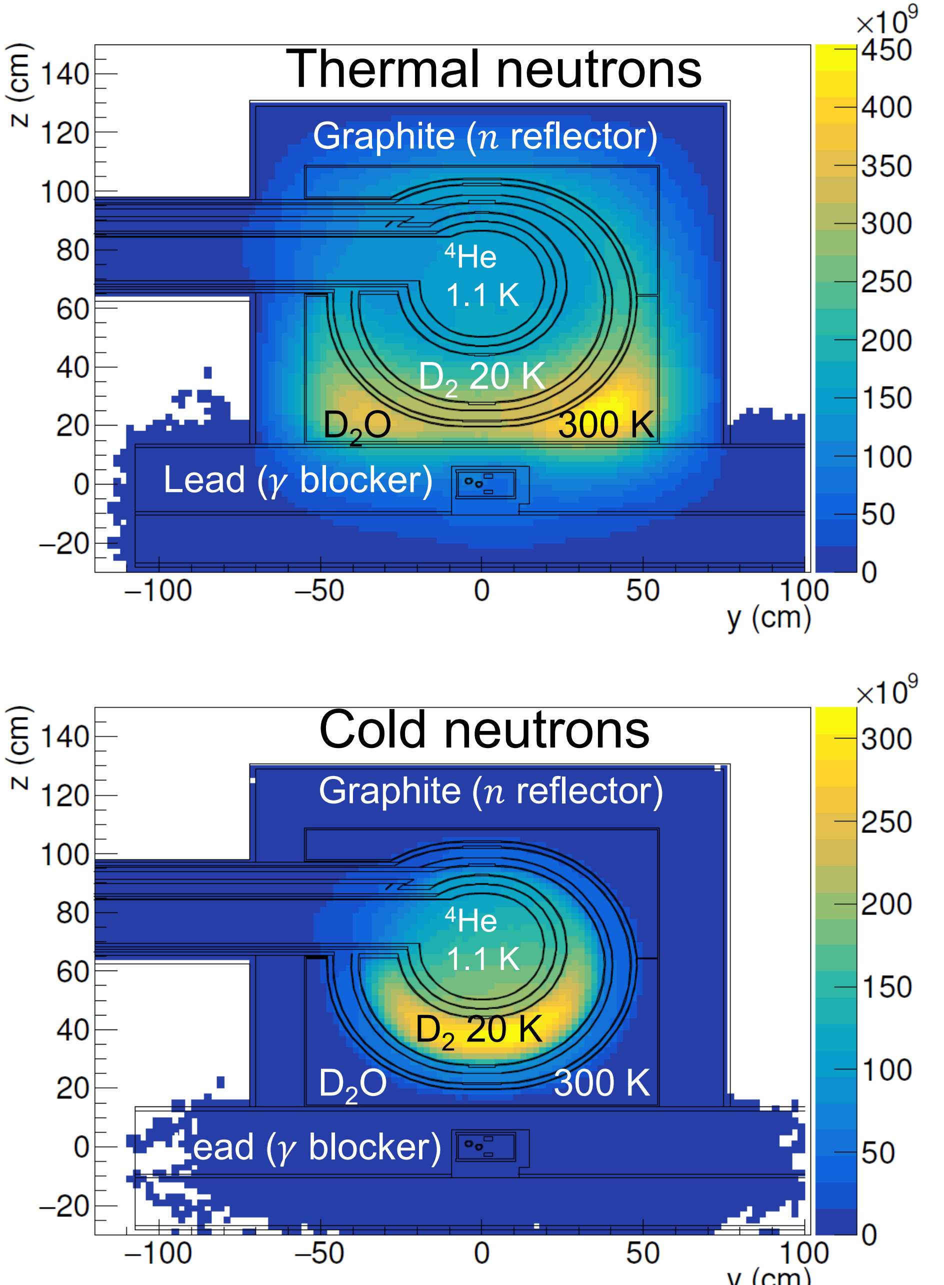
Temperature profile at the center of the target.

Step 2: Moderation by elastic scattering.

The moderation is made in:

- 546 L of room temperature **heavy water**
- 125 L of 20 K **liquid deuterium**



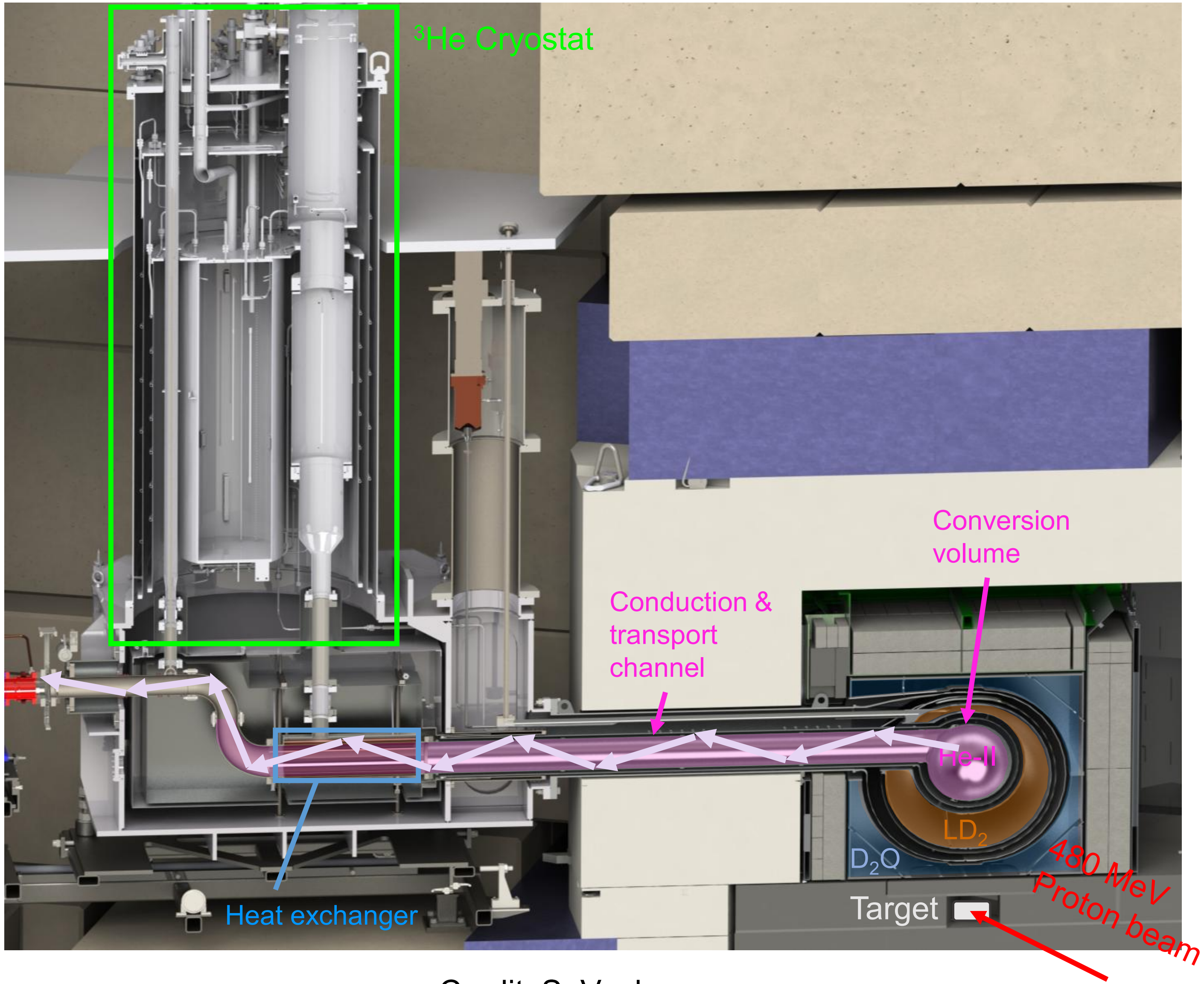


Credit: W. Schreyer

Step 3: Superthermal conversion to UCNs

Cold neutrons are converted to UCN in isopure ^4He kept below 1.1 K and diffuse in transport channel towards experimental area.

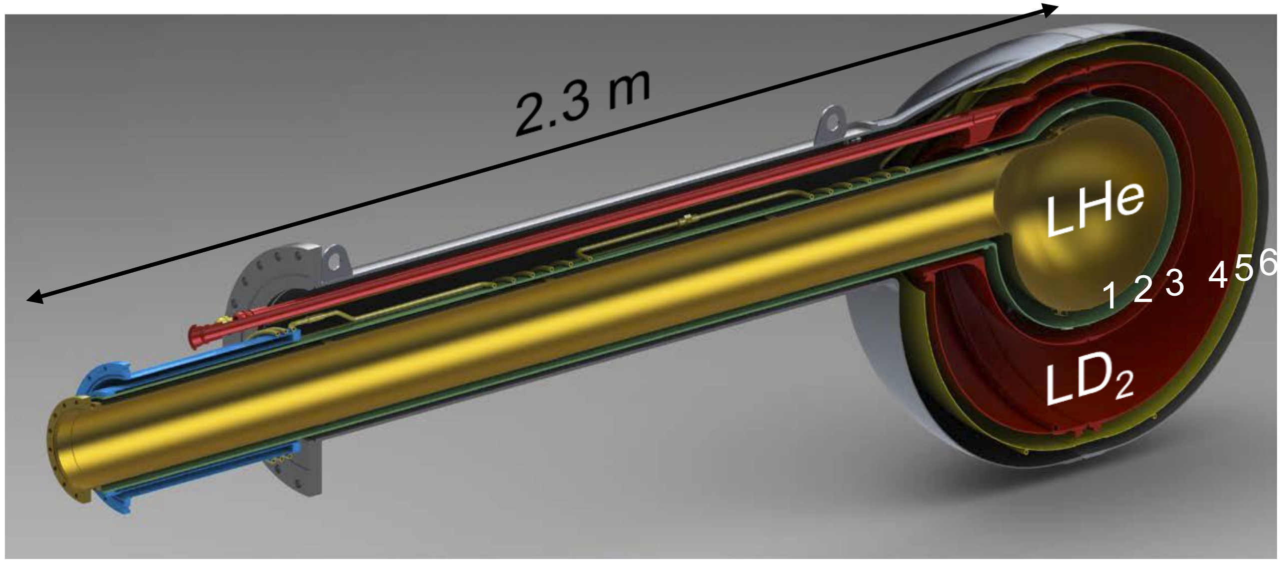
The temperature of the isopure ^4He, exposed to 10 W of beam heat load is kept by the ^3He cryostat connected and the heat exchanger.



Credit: S. Vanbergen

The tail section

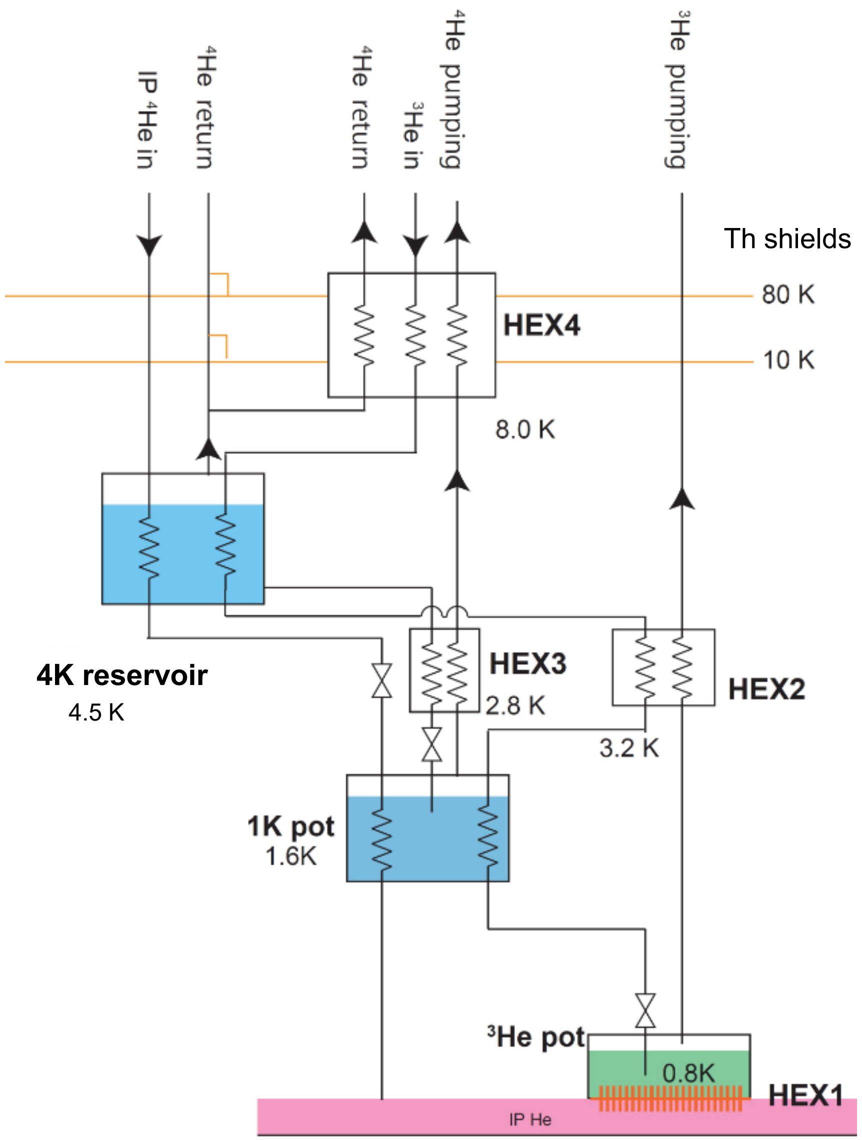
- Six welded aluminium layers
  1. Superfluid He vessel
  2. He/D2 vacuum separation (able to withstand 21 bar D2 explosion pressure) and 20 K thermal shield
  3. Inner LD2 vessel wall
  4. Outer LD2 vessel wall
  5. 100 K thermal shield
  6. Outer vacuum vessel



- Layer 1 completed and UCN storage lifetime validated at LANL in December 2020 (https://doi.org/10.1016/j.nima.2023.168106)

- Layer 6 welding and installation completed April 2024

^{3}He cryostat



- 4He pumping system to reach 1.6 K
- 3He pumping system to reach 0.8 K
- Designed to cool 3He to ~0.8 K with 10 W heat load
- Performance in 2024: ~0.9 K with 10 W heat load

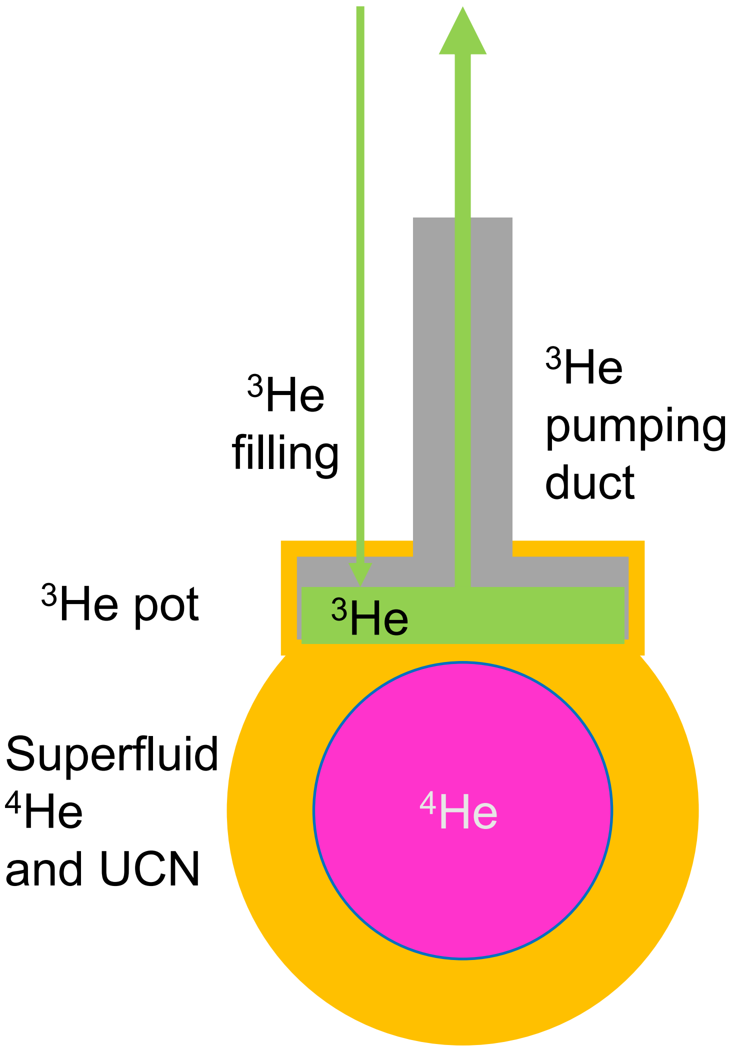
^{3}He cryostat pumping system:

The 4K pot is filled by the ^{nat}He purifier with a ~40 l/h capability.

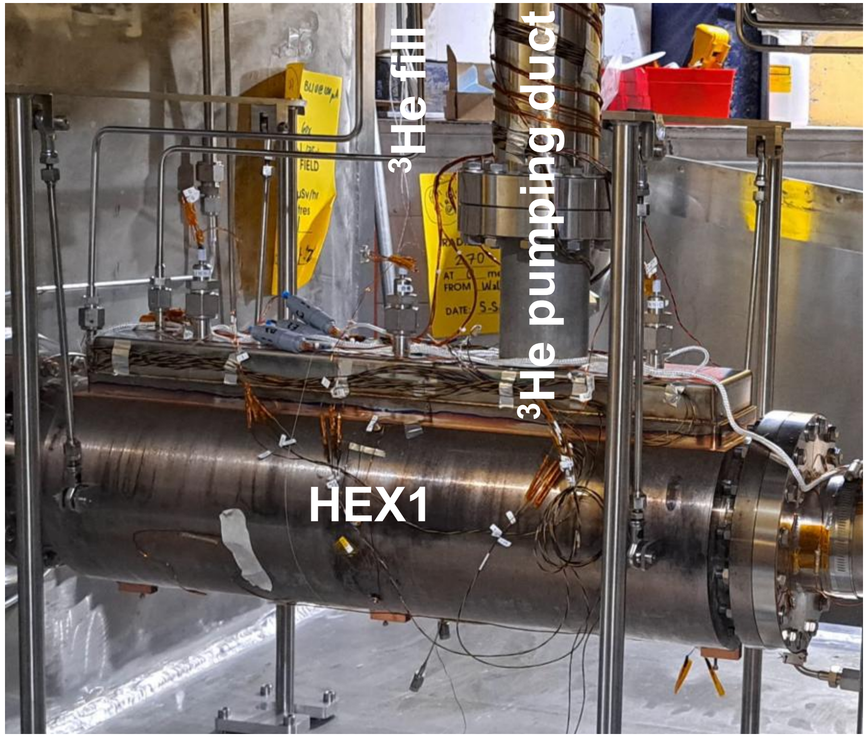
The 1K pot and 3He are cooled down by the 3 sets of Busch pumps.

	Mass Flow [g/s]	Flow [m^3/h]	Vacuum [Torr]
^{3}He	0.57	4650	2.5
^{nat}He	0.607	1900	4.83

HEX1 Heat Exchanger

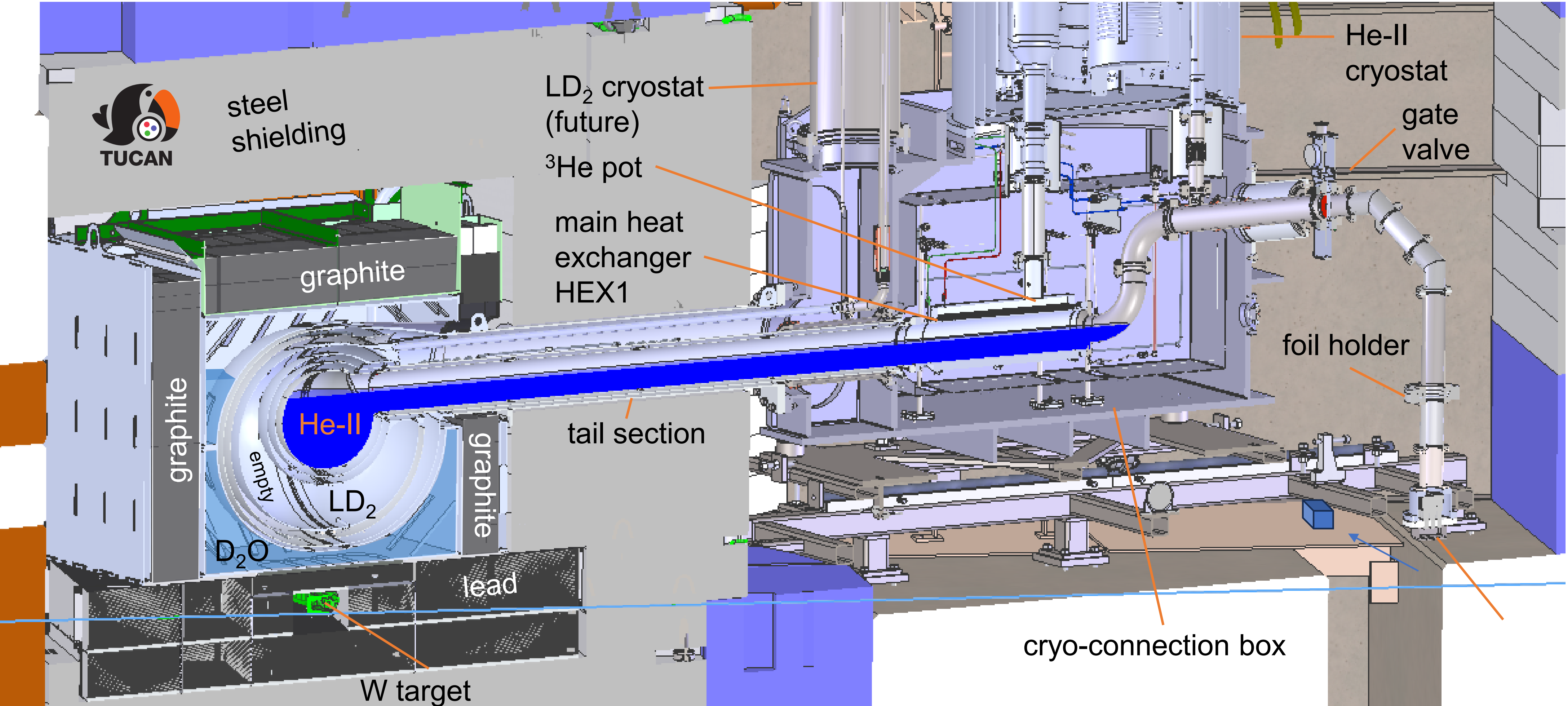


- Cold liquid ^{3}He drops into a pot
- The boiling ^{3}He in the pot removes heat from the superfluid ^{4}He via a copper heat exchanger (HEX1)
- Boiling ^{3}He is pumped away by very big pumps

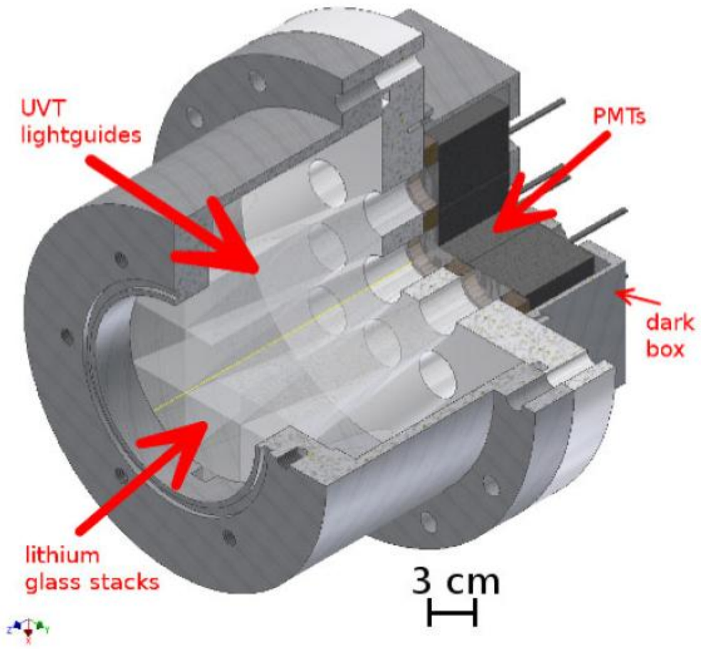


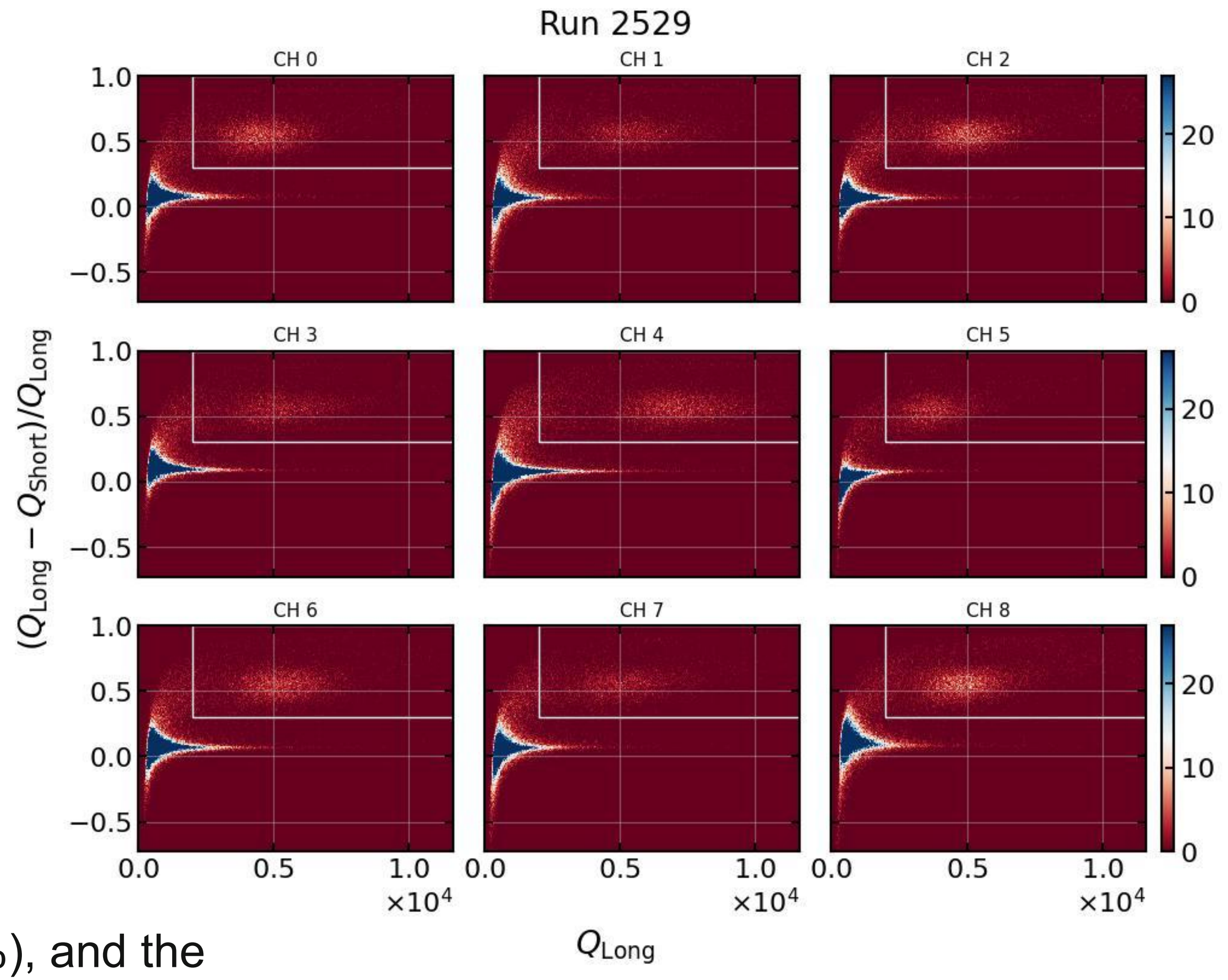
June 2025 UCN production tentative

- 390 L of heavy water (546 L at full capacity)
- No LD_2
- 27 cm of isopure ^4He (36 cm at full capacity)



UCN detectors



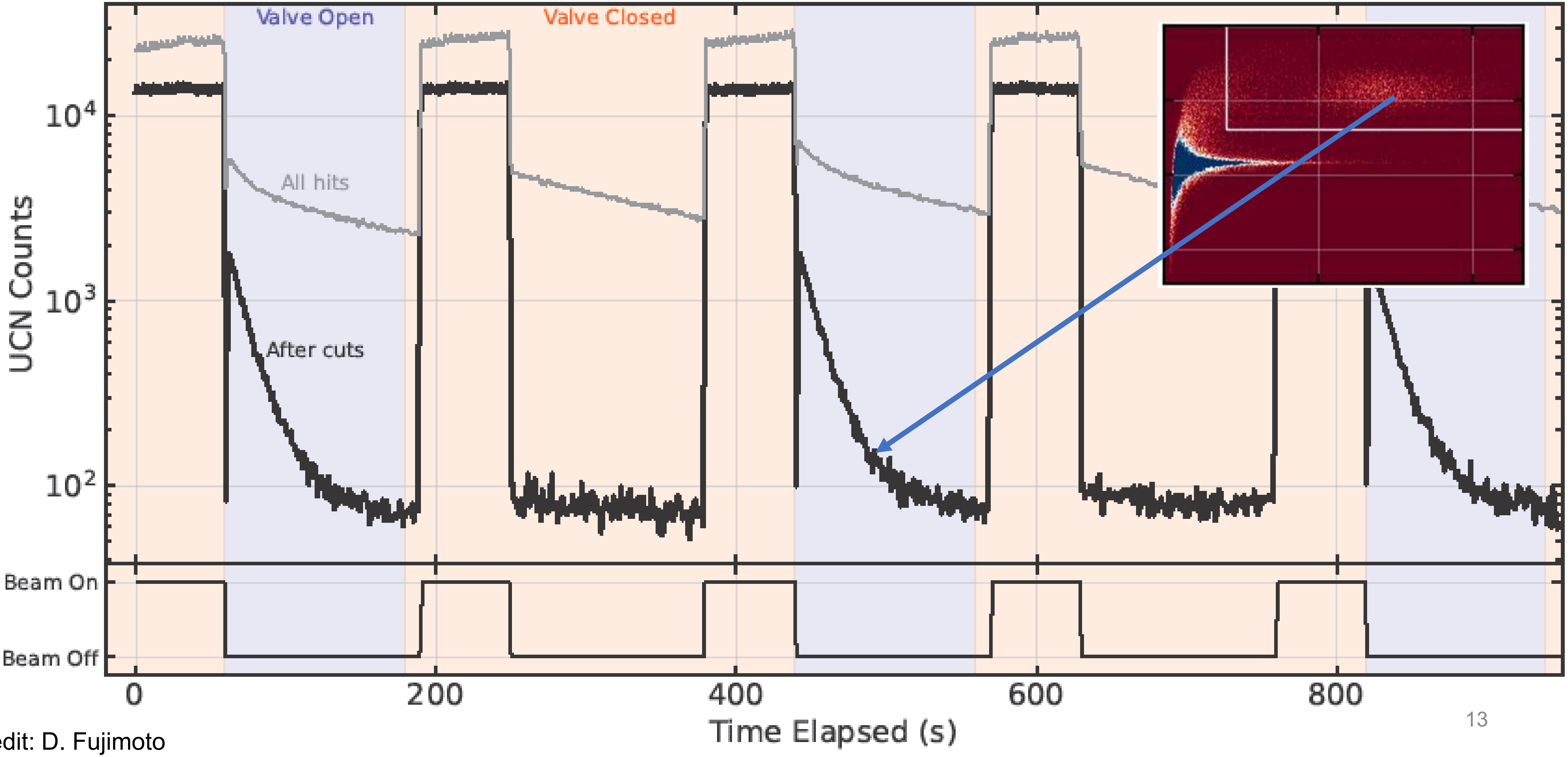


Scintillating stacks Lithium detector:

- ^{6}Li + $n \rightarrow \alpha$(2.05MeV) + t(2.73MeV)
- The upper layer is 60 μm thick depleted ^{6}Li glass (0.01 %), and the lower layer is 120 μm thick doped ^{6}Li (95 %) glass. Ensure energy deposition in scintillating glass.
- Fast signal 6 ns rise time 55 ns fall time allows for MHz detection. 89.7 % efficiency

First UCN production

Friday June 13th, 2025
10:34 am

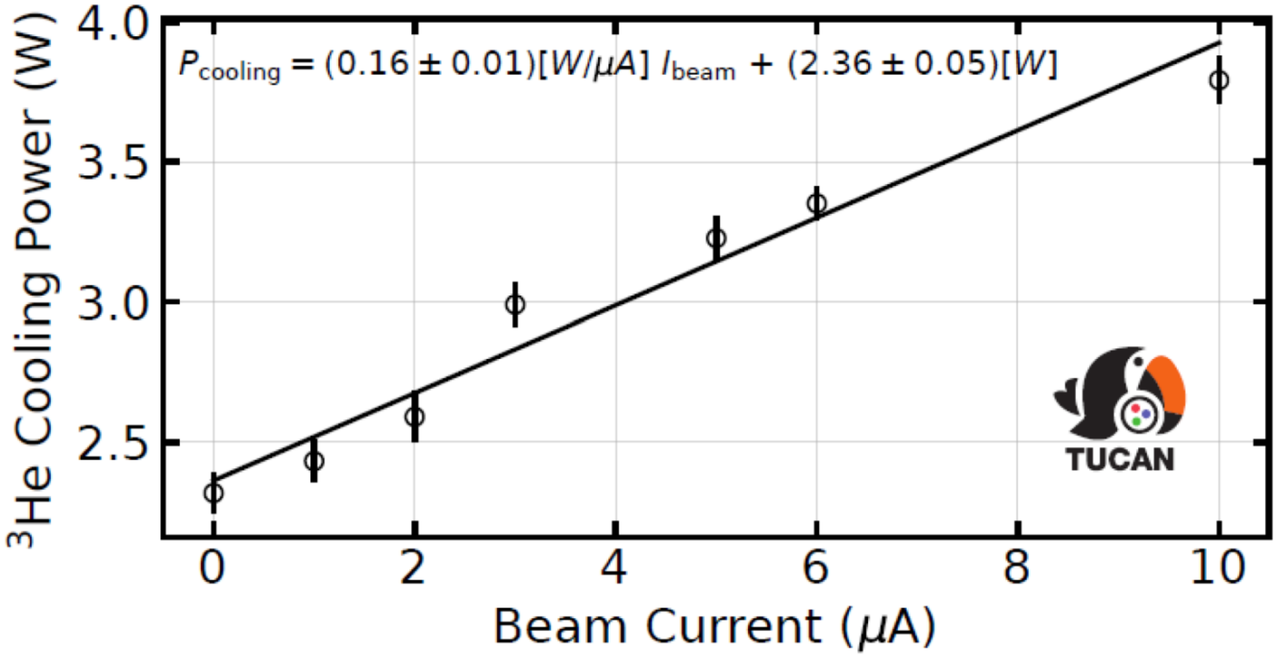


Credit: D. Fujimoto

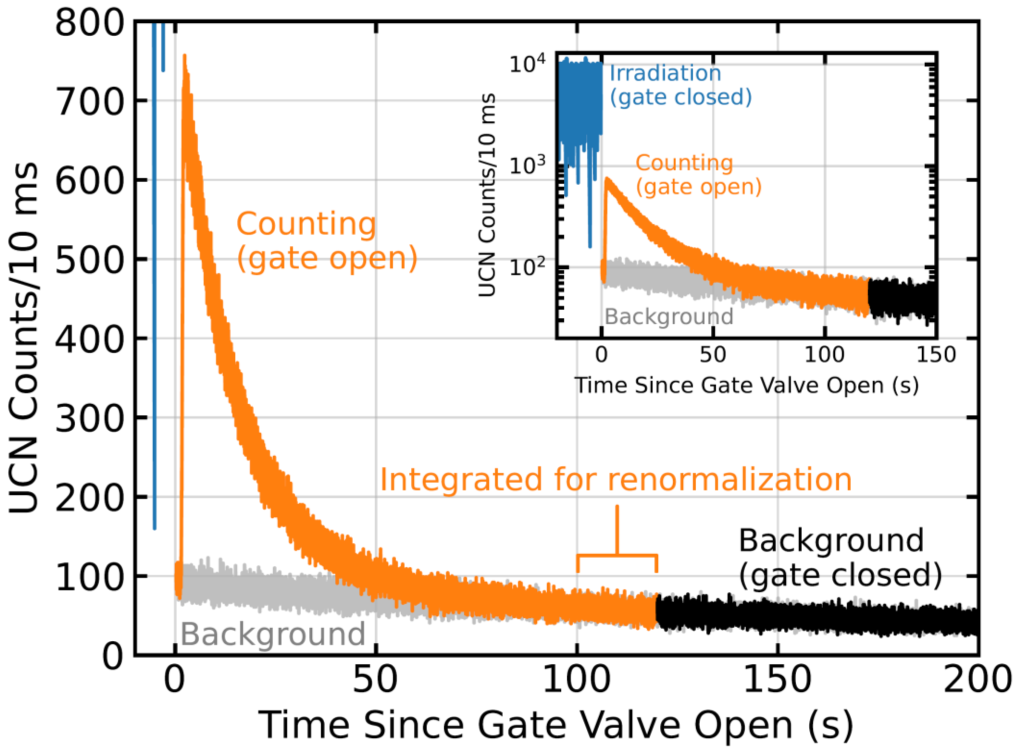
Results:

arXiv:2509.02916 **[nucl-ex]**

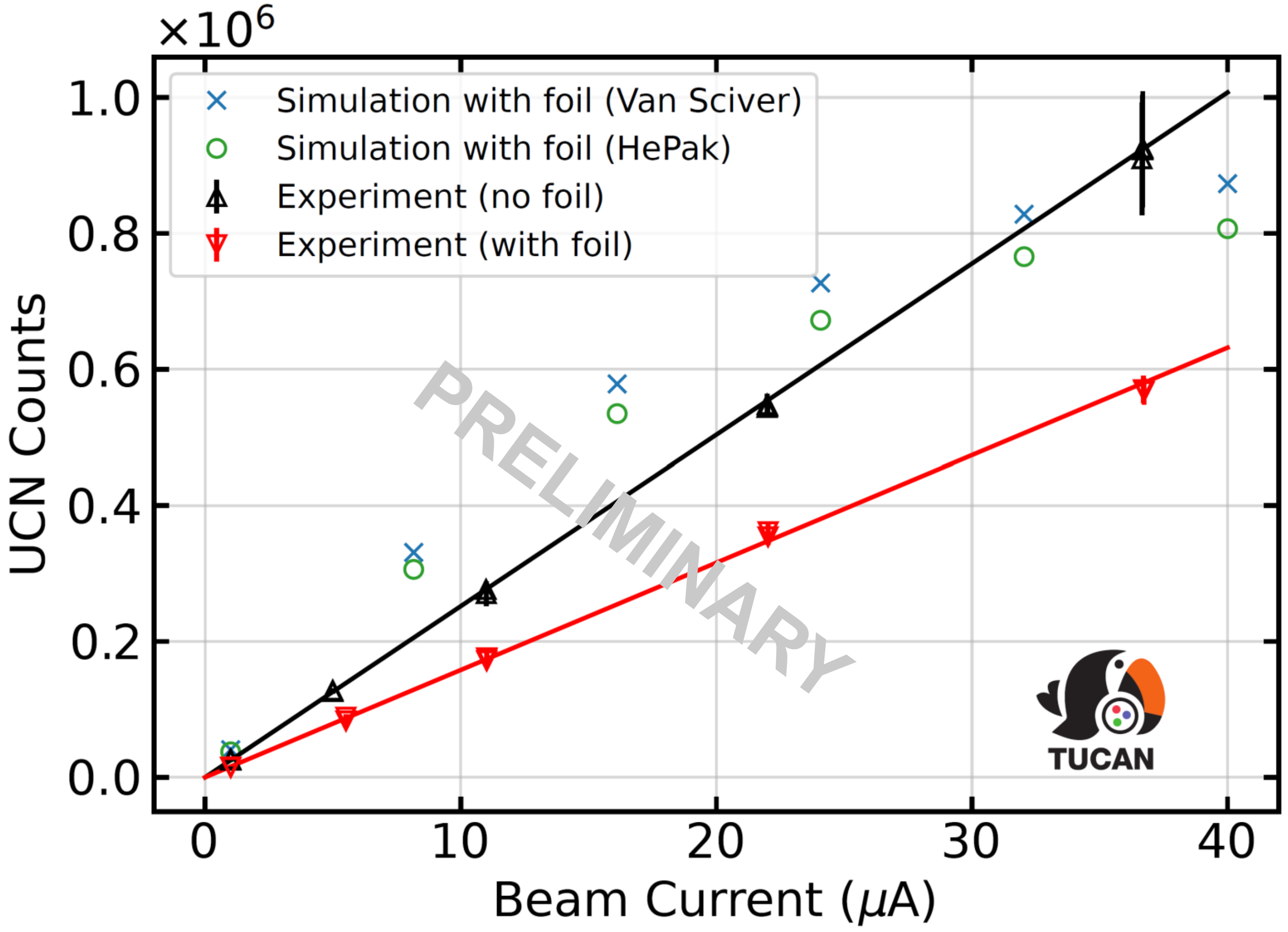
- Vapor pressure in tail section consistent with superfluid isopure ^{4}He temp of 0.9-1.1K
- Beam heat load matched estimation



Example Data after 60s proton irradiation time



Count rate vs beam current:



Simulation package includes:

- MCNP of the source geometry
- UCN production
- PENTrack for UCN transport

Measurement in reasonable agreement with simulations.

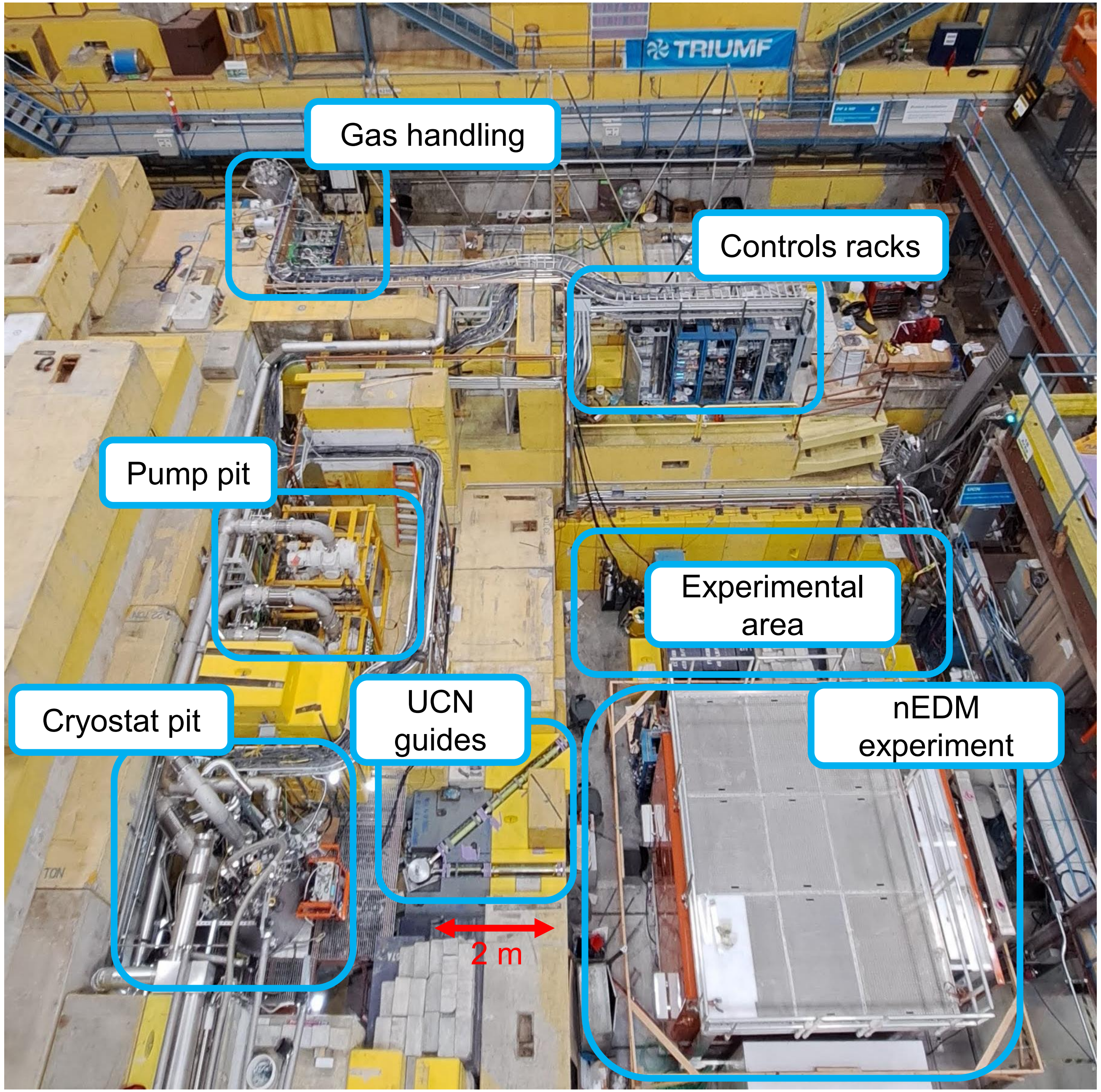
Source storage lifetime ~25-30 seconds.

First UCN production does not show saturation at high beam current! Maybe sources like ours can support higher neutron fluxes than anticipated.

Credit: D. Fujimoto

CONCLUSION

- The TUCAN collaboration produced its first UCN in June 2025.
- First results are very promising and more cryogenic study need to be done to fully understand them.
- The source will be completed and fully commissioned by the end of the year (x76 UCN production).
- The nEDM experiment will be built in 2026 and commissioned in 2027.



The experimental area will be open to users.

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TRIUMF Ultracold Advanced Neutron Collaboration

March 2025 Collaboration Meeting, TRIUMF

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THE UNIVERSITY OF WINNIPEG
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