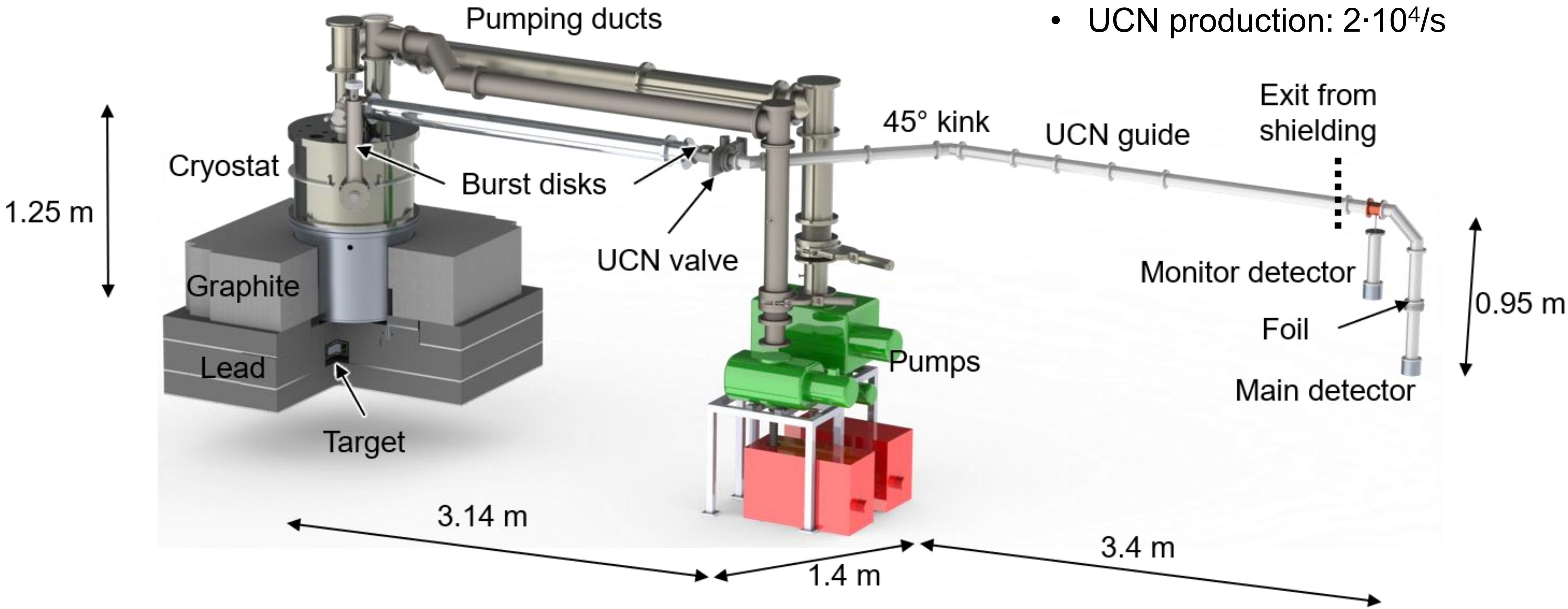
TRIUMF

Experiments with the vertical UCN source

Wolfgang Schreyer

Vertical source shipped to TRIUMF 2016

- Beam on target: 1 µA (0.5 kW)
- Cooling power: ~0.1 W
- Production volume: 8 L
- Cold moderator: solid D_2O
- UCN production: $2 \cdot 10^4$/s



Experimental runs

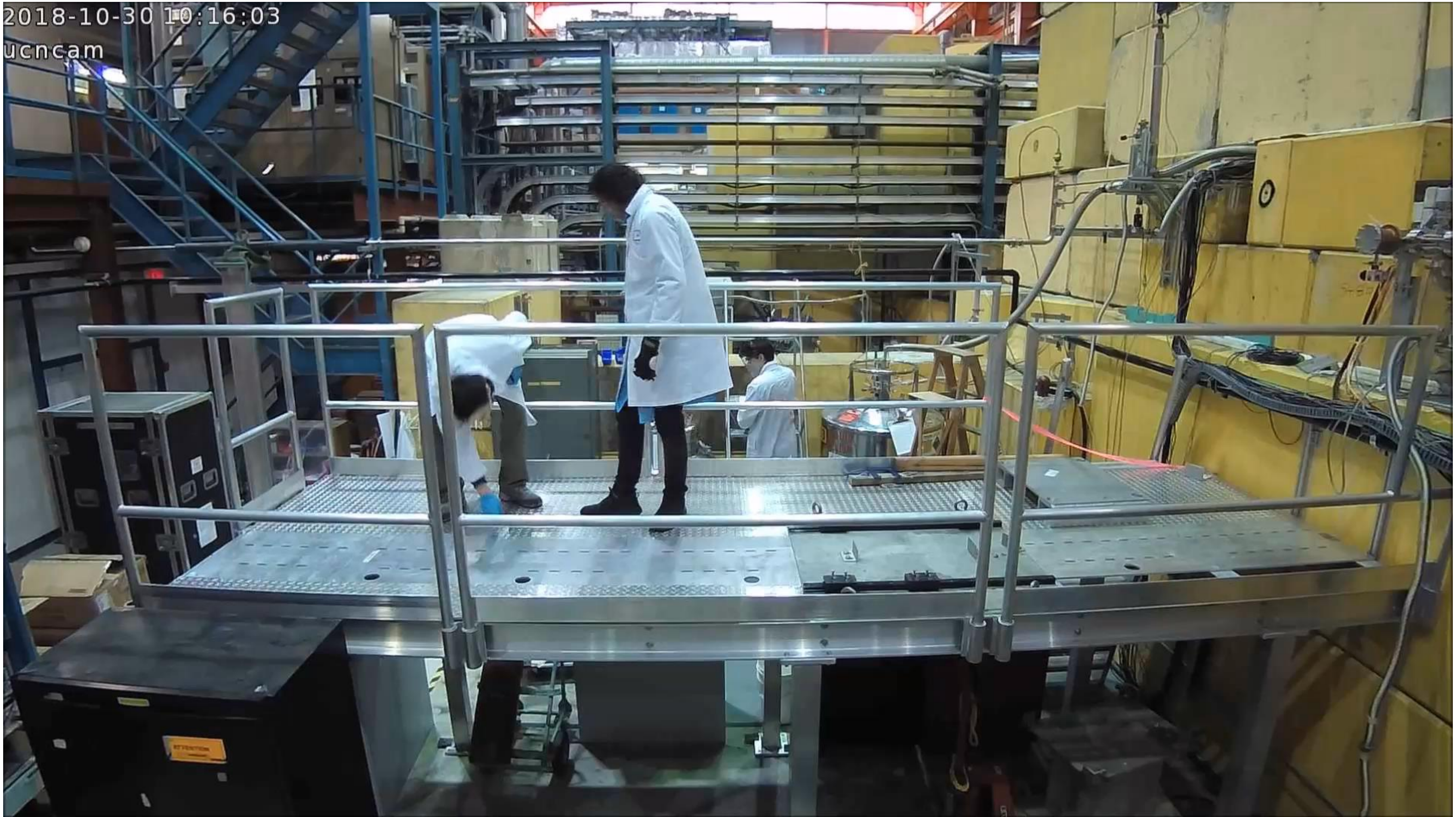
Three runs

- 2 – 4 weeks of UCN experiments in each 2017, 2018, and 2019
- 4 – 6 weeks of three-shift schedule each, **whole collaboration contributed**
- Weeks of preparation & cooldown
- Months of hardware development with great support from TRIUMF machine shop & SciTech
- 60+ experimental setups total
- Run 2019 aborted after two weeks due to clogging in ^{3}He cooling circuit

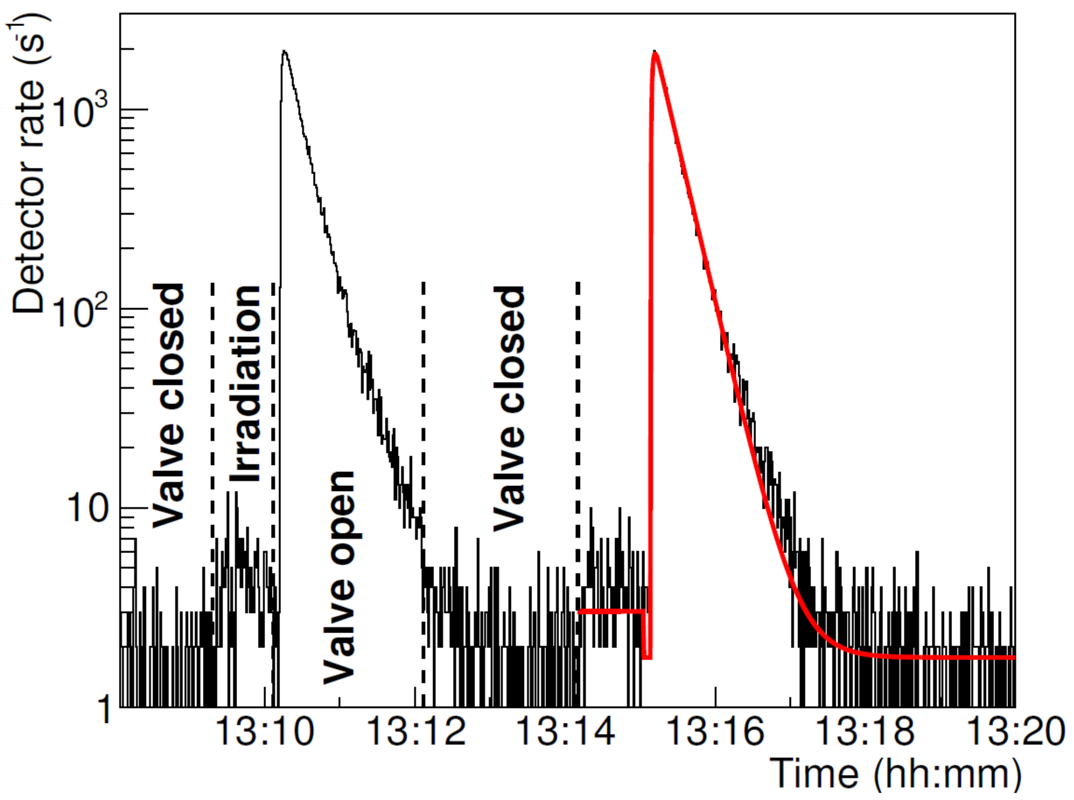
Goals

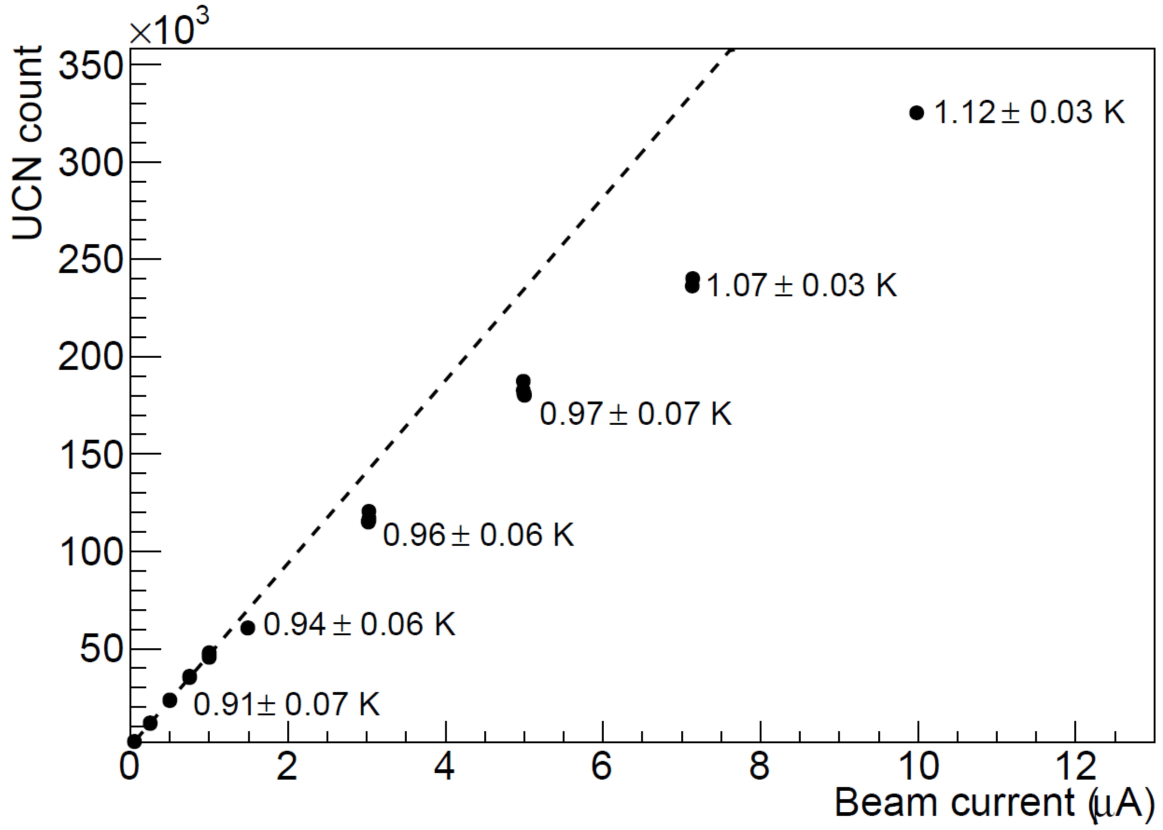
- Understand superfluid-helium source
- Qualify parts for new UCN source and nEDM
  - Transmission
  - Storage lifetime
  - Valves
  - Guides
  - Detectors
  - Polarizers

2018 run



First ultracold neutrons produced at TRIUMF 2017

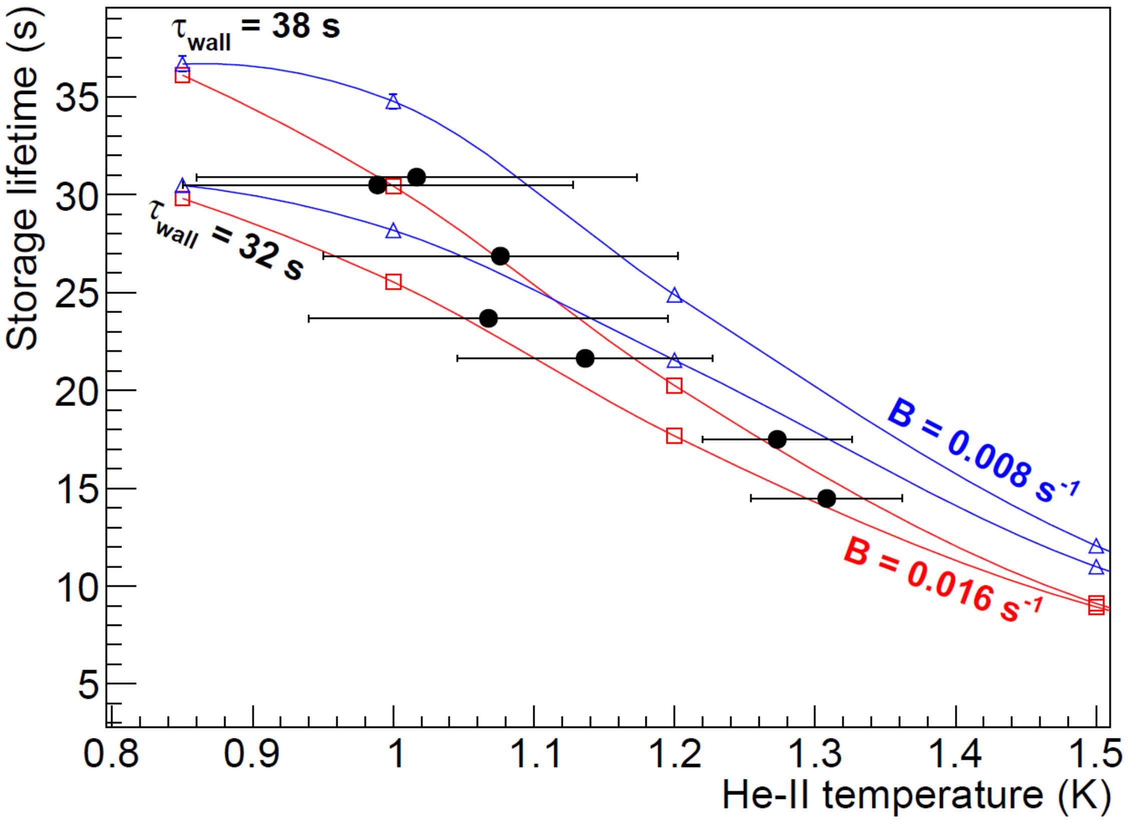




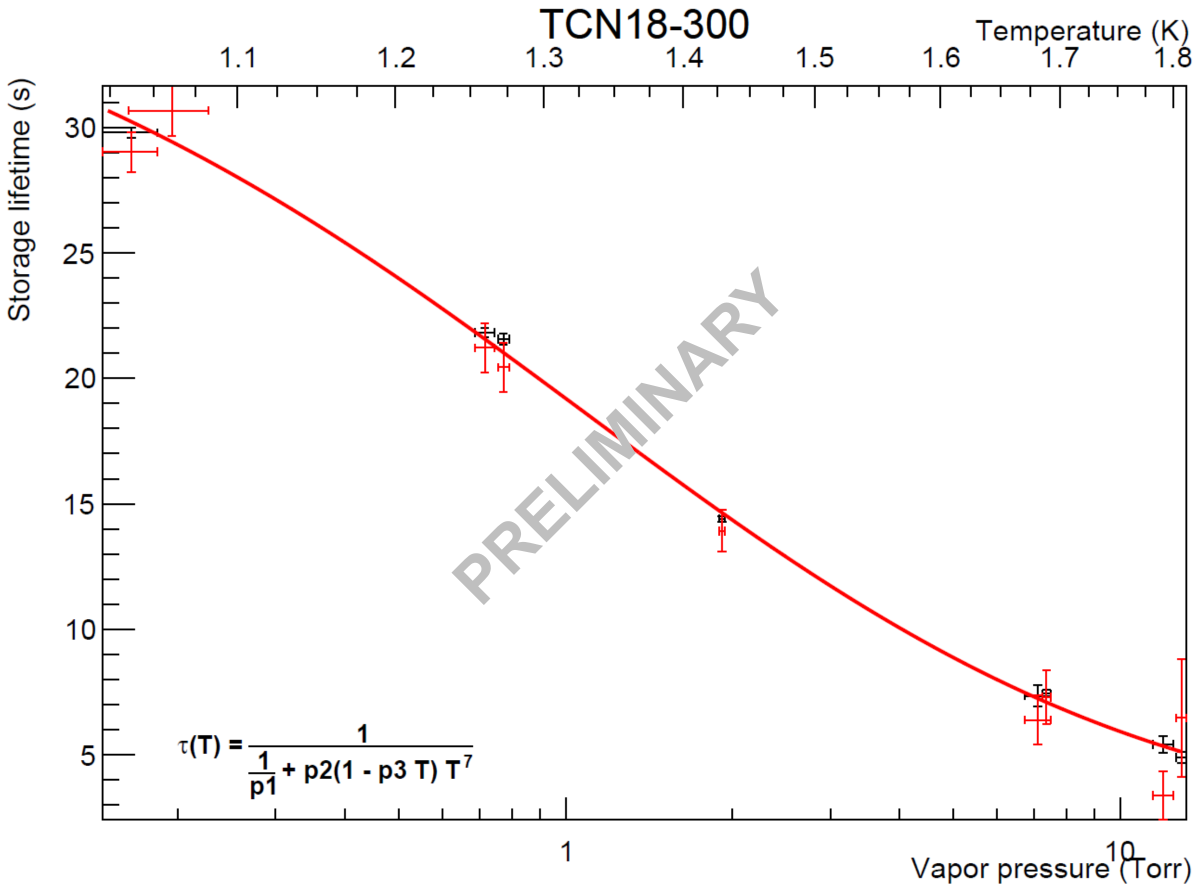
Extracted up to 325000 UCN @ 10 μA
70000 UCN @ 1 μA

published in 10.1103/PhysRevC.99.025503

Storage lifetime in source varies with temperature

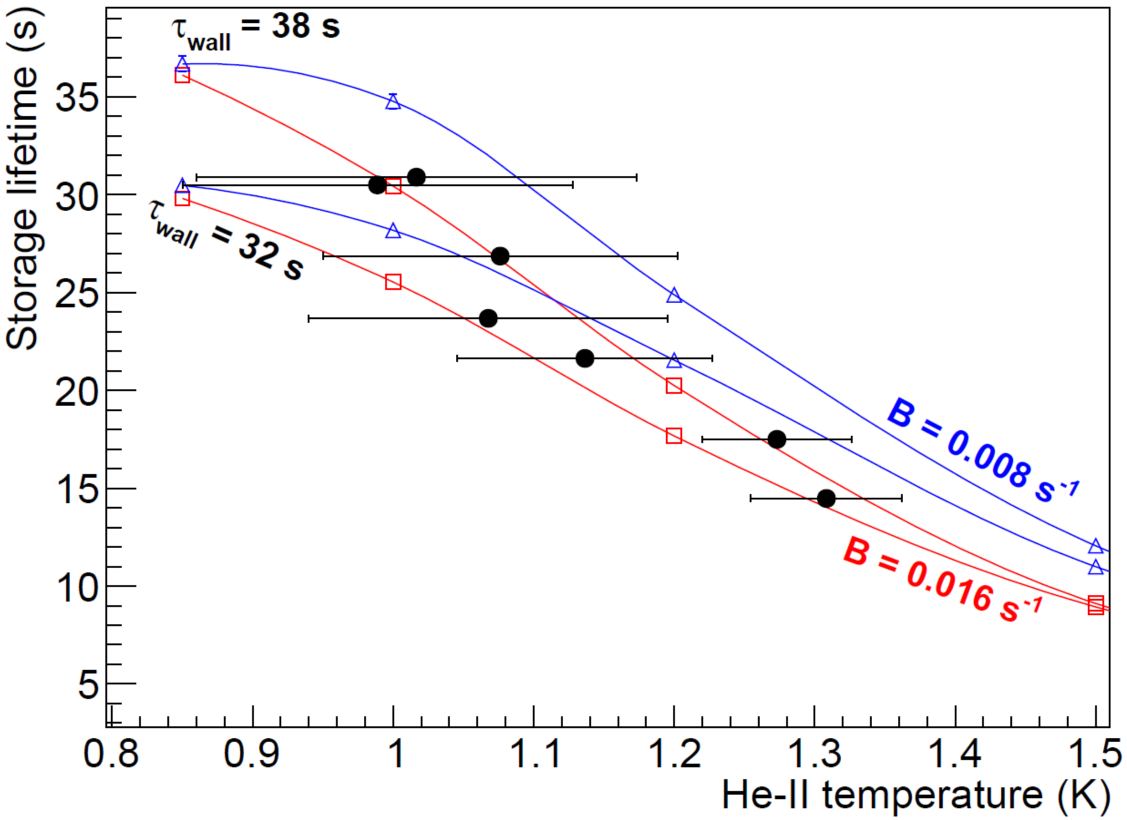


2017: Reasonable agreement with MCNP + PENTrack simulations



- 2018: Improved vapor-pressure & temperature measurements
- Poor correlation between vapor pressure and T sensors below 1.2 K
- Heat conduction in He-II likely limiting factor for this source

Storage lifetime in source varies with temperature



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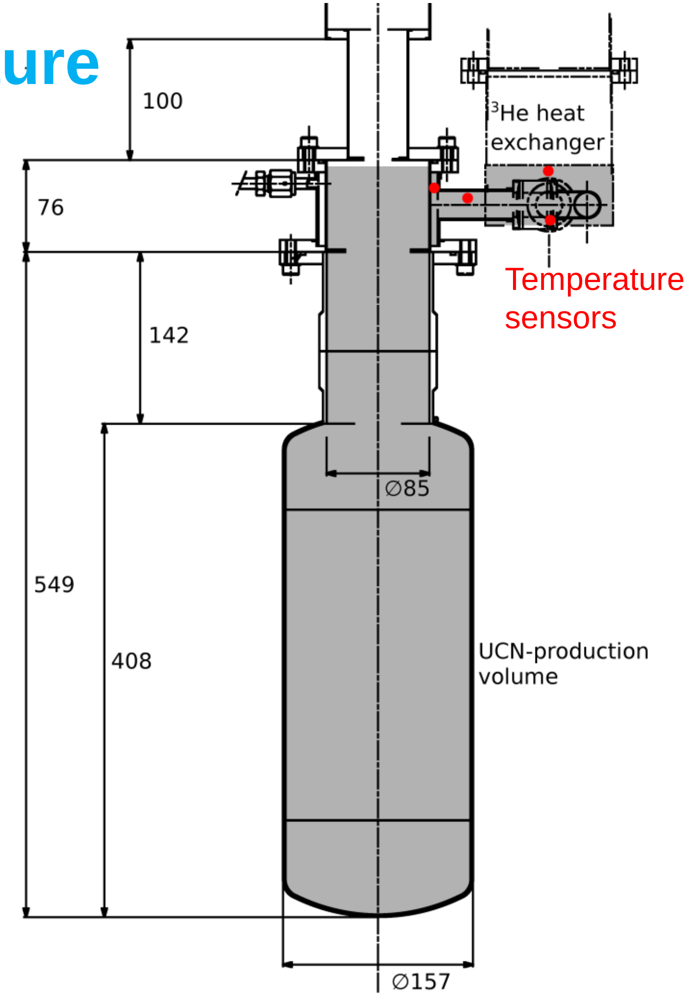

- 2018: Improved vapor-pressure & temperature measurements
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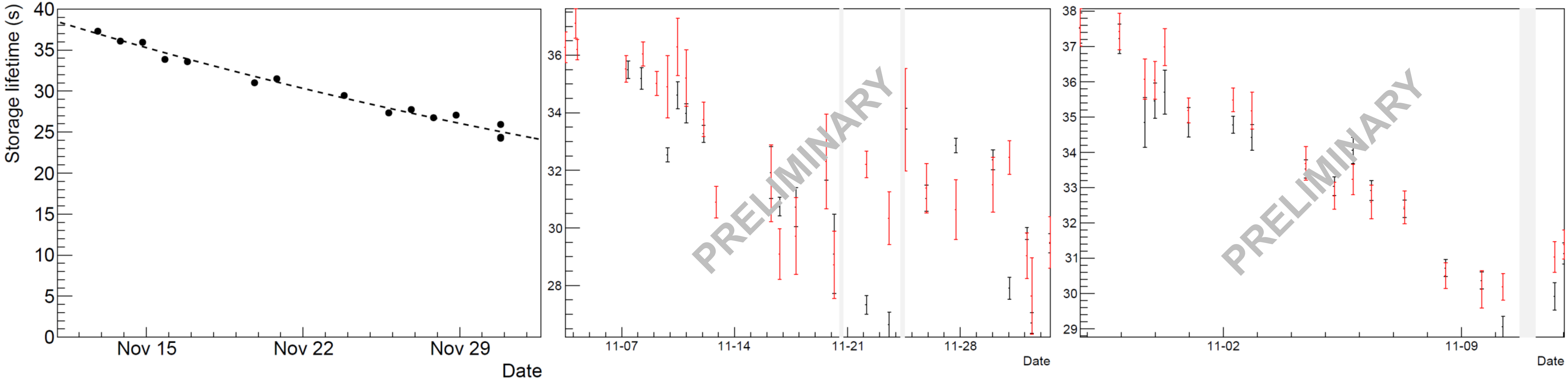
Storage lifetime in source varies with time

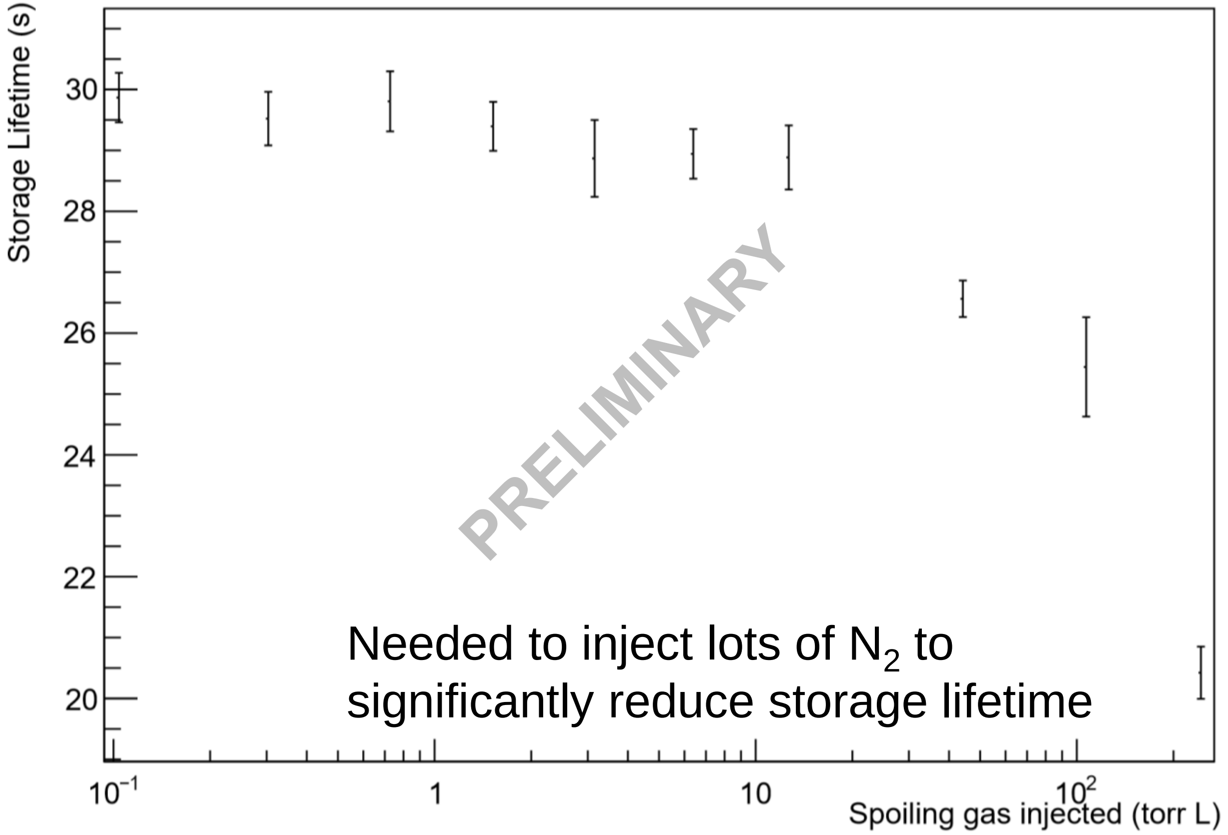


2017: Steady drop from 37s to 25s over 18 days

2018: Fluctuations, higher & unstable temperatures, drop from 37s to 29s over 30 days

2019: Steady drop from 37s to 30s over 15 days

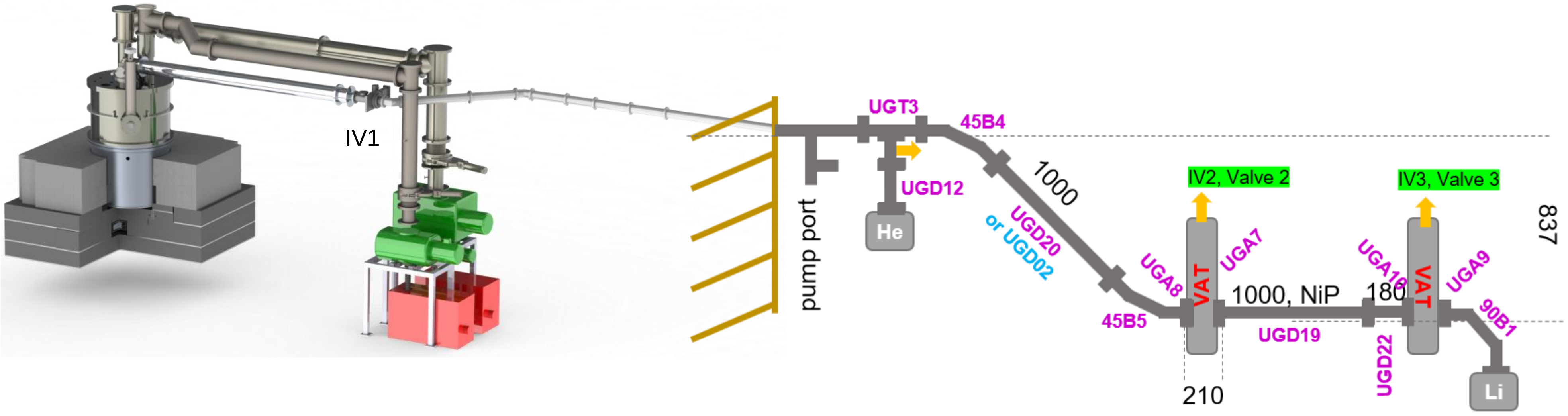
Storage lifetime in source varies with time



Needed to inject lots of N_2 to significantly reduce storage lifetime

- Explained by neither temperature increase nor nitrogen leakage in superfluid helium
- Normalization method is needed to properly measure transmission/storage lifetime of UCN hardware

Transmission measurements



2018:

(0) Start with IV1, 2, 3 closed
(1) Irradiation time with IV1 open (60s)
(2) Counting with IV2 & IV3 open (120s)

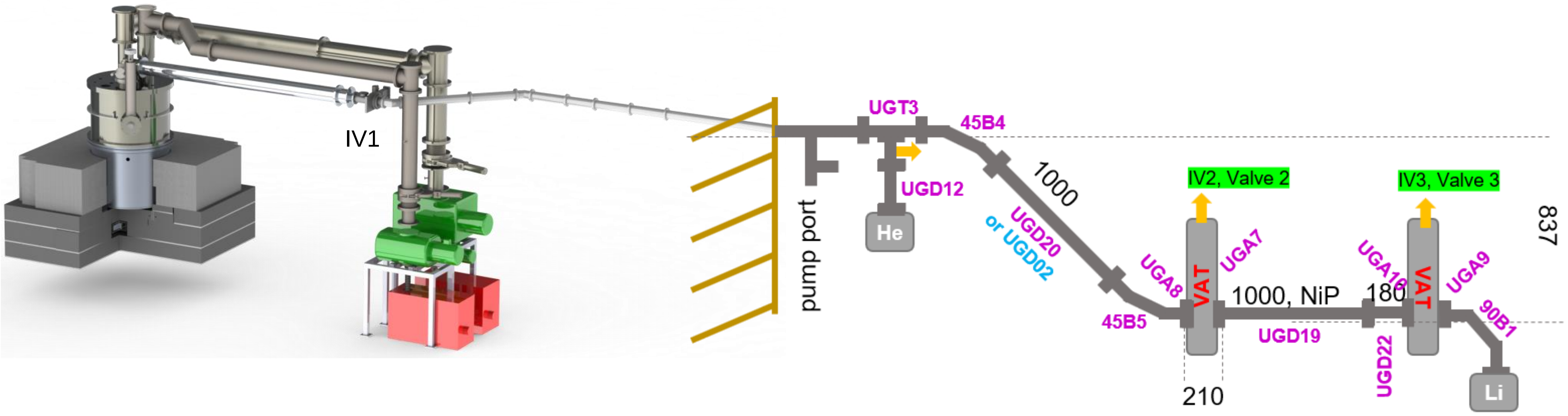
Transmission = Li counts(2)/He counts(1)
Or transmission = Li counts(2)/He counts(2)
Affected by source during (1) and (2)

Pre-storage method (2019):

(0) Start with IV1, 2, 3 closed
(1) Irradiation time with IV1 open (60s)
(2) Pre-storage time with IV1 closed (15s)
(3) Counting with IV2 & IV3 open (120s)

- Transmission = Li counts (3)/He counts(2)
- Not affected by source during (2) and (3)!
- Optimized with simulations
  © Sean Vanbergen

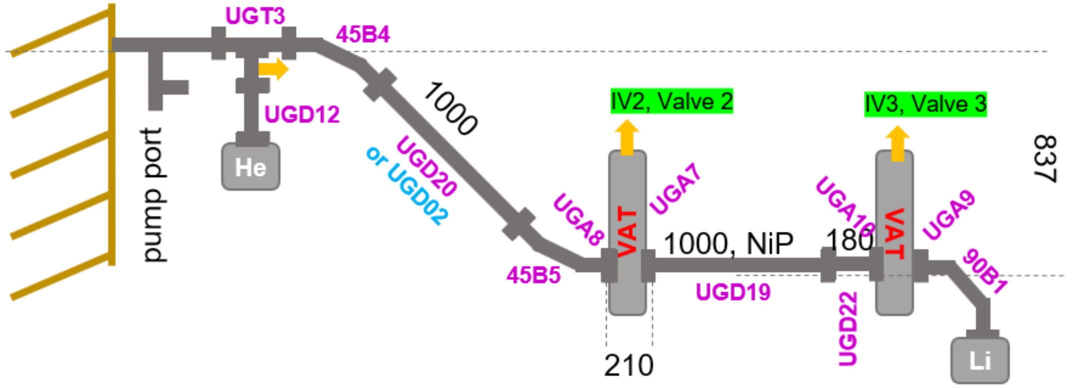
Storage-lifetime measurements



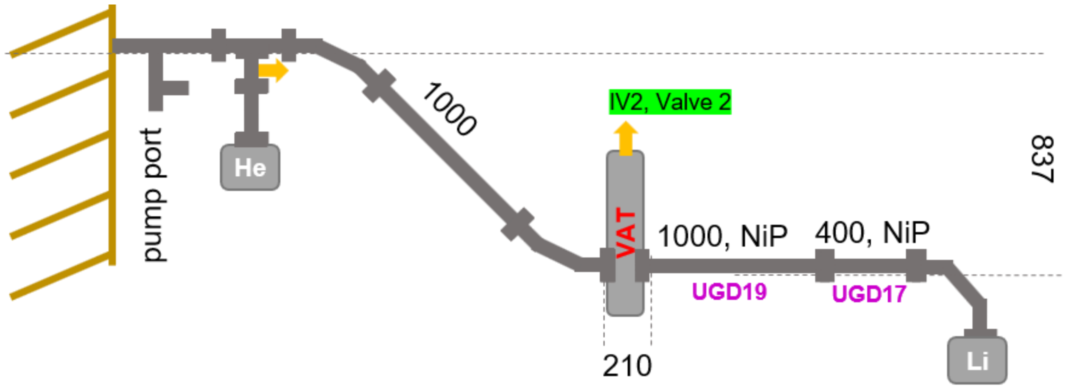
(0) Start with IV1, 2, 3 closed
(1) Irradiation time with IV1 & IV2 open (fill up to IV3) (60s)
(2) Store between IV2 & IV3, IV1 closed (2s – 120s)
(3) Counting with IV3 open (120s)

2019:
Use He counts during (2) and (3) for normalization

UCN valves



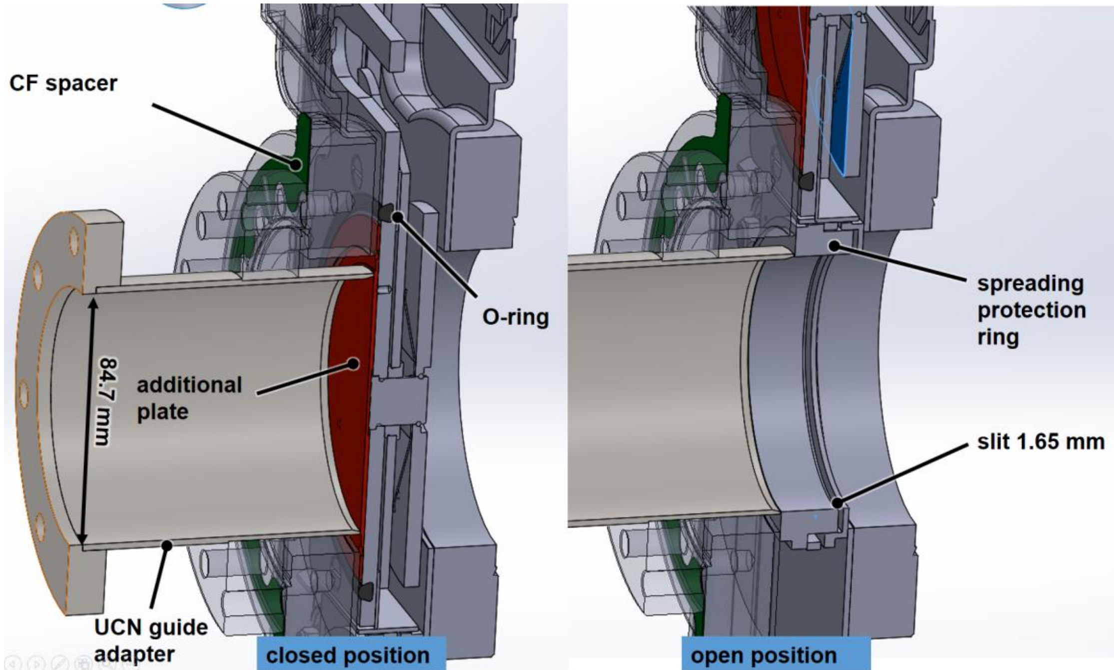
Compare setups with and without IV3



Off-the-shelf VAT valves

© Ruediger Picker, Dennis Stang

- Transmission relative to guide: 90%
- Improvements between 2018 and 2019: Storage lifetime 16 s → 36 s



Guides

Japanese standard (85 mm ID)

- Bare stainless steel
- NiP-coated stainless steel
- NiMo-coated glass, NiP-coated Al adapters
- Copper

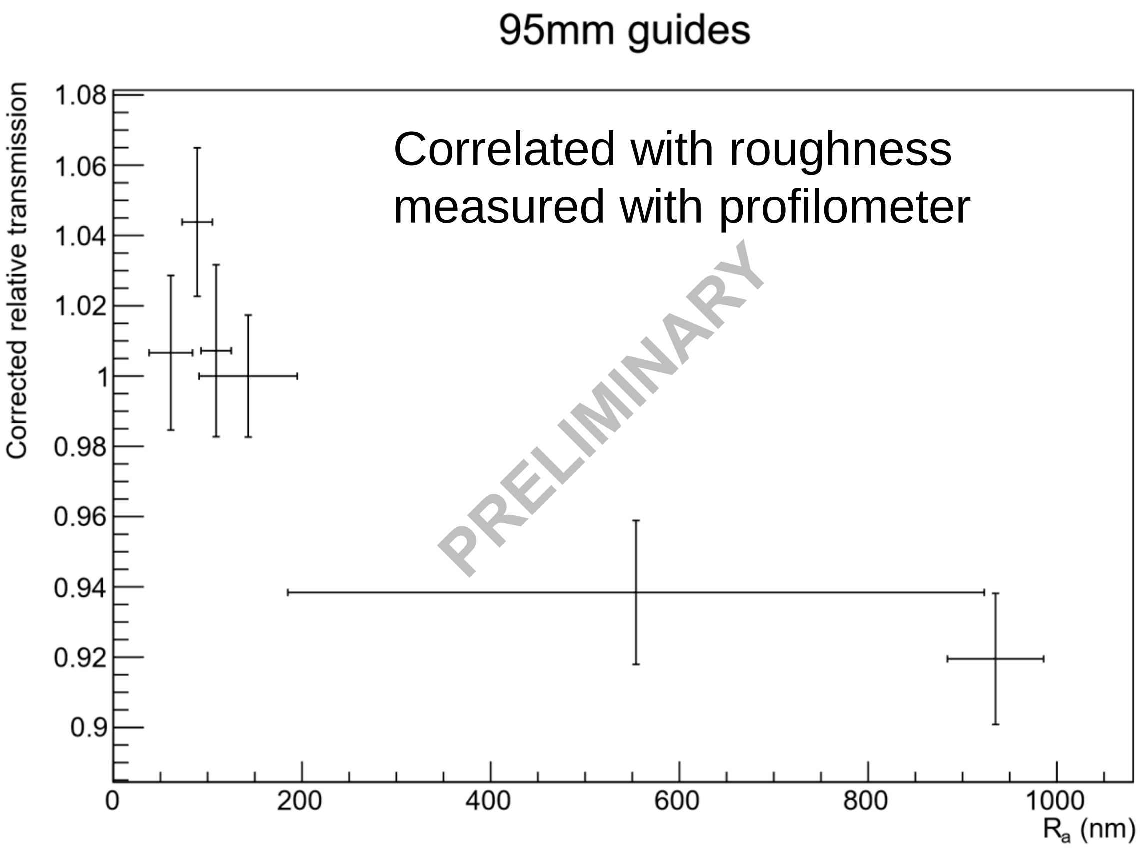
TUCAN standard (95 mm ID)

© TRIUMF, Russell Mammei, Shinsuke Kawasaki

- Al (75 nm polish) + NiP (ChemProcessing)
- Al (750 nm polish) + NiP (ChemProcessing)
- Al (75 nm polish) + NiP (AST)
- SS (75 nm polish) + NiP (AST)
- SS (75 nm polish) + black NiP (AST)
- SS + NiP (10 nm polish) (UFT)
- Al (75 nm polish) + NiP (ChemProcessing) + repolish

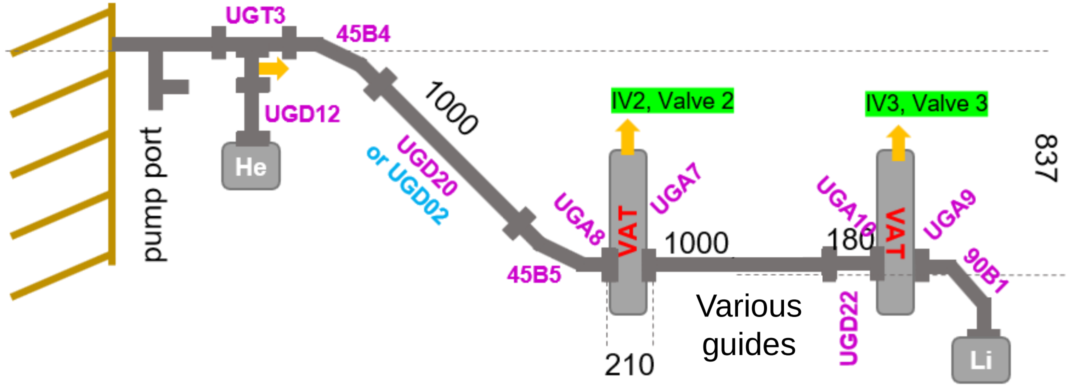
Polishing by Irving, Kenosha WI, USA irvinginc.com
Chem Processing, Rockford IL, USA chemprocessing.com
AST Advanced Surface Technologies, Arvada CO, USA astfinishing.com
UFT Ultra Finish Technology, Japan uft.co.jp

Guide results

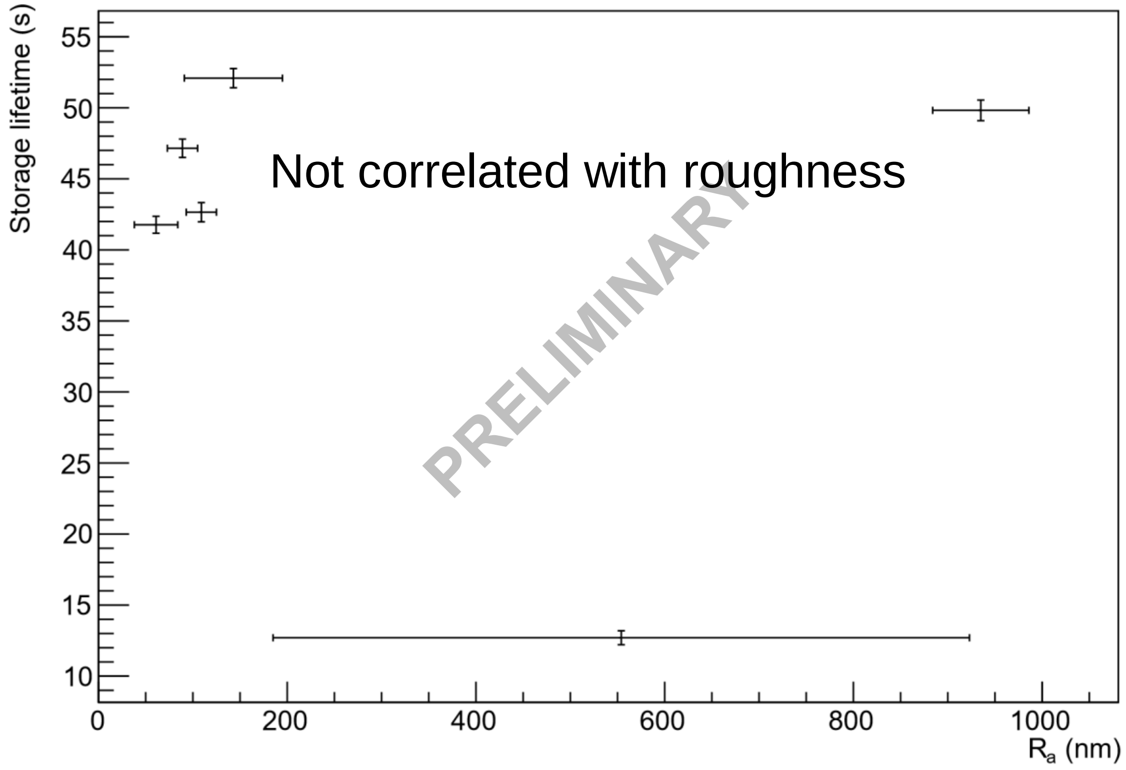


Transmission of 1m-long guides

- SS = SS + NiP
- Glass + NiMo 90%, copper 75%
- 95mm guides identical (+/- 2%) except rough guide (92%) and black NiP (94%)
- Profilometer measurements: NiP coating increases roughness by 25% to 100%



Guide results



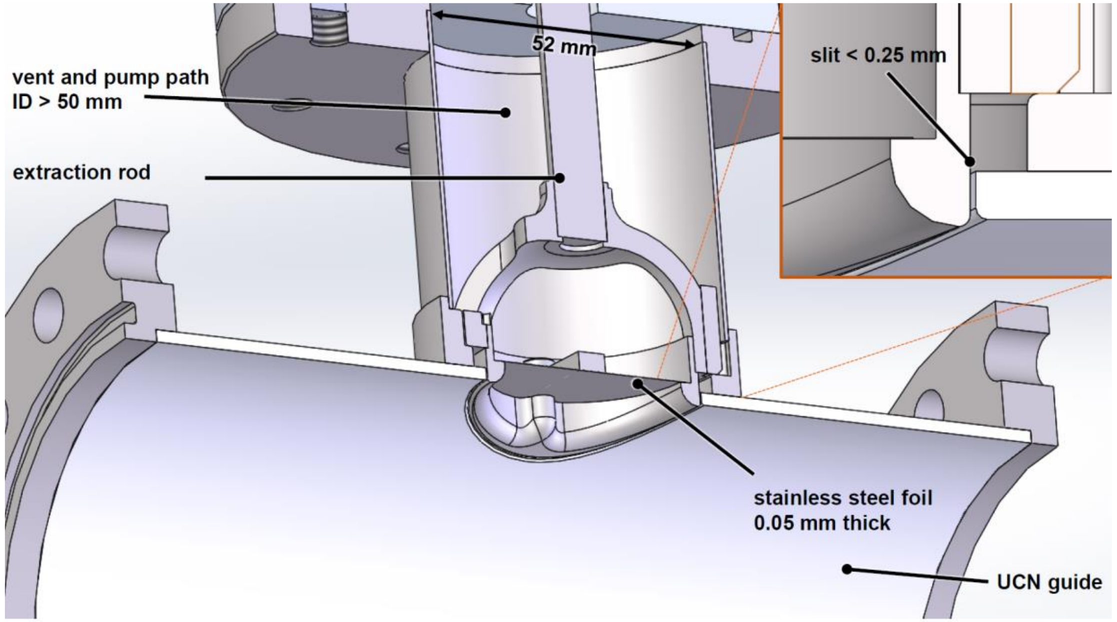
Storage lifetime

- ChemProcessing: 50 – 52 s
- AST: 42 – 47 s
- UFT: 42 s
- Black NiP: 12 s (!)
- Not correlated with roughness
- Issues with porous welds in Al

Helium barriers

Overpressure vent
© Cam Marshall

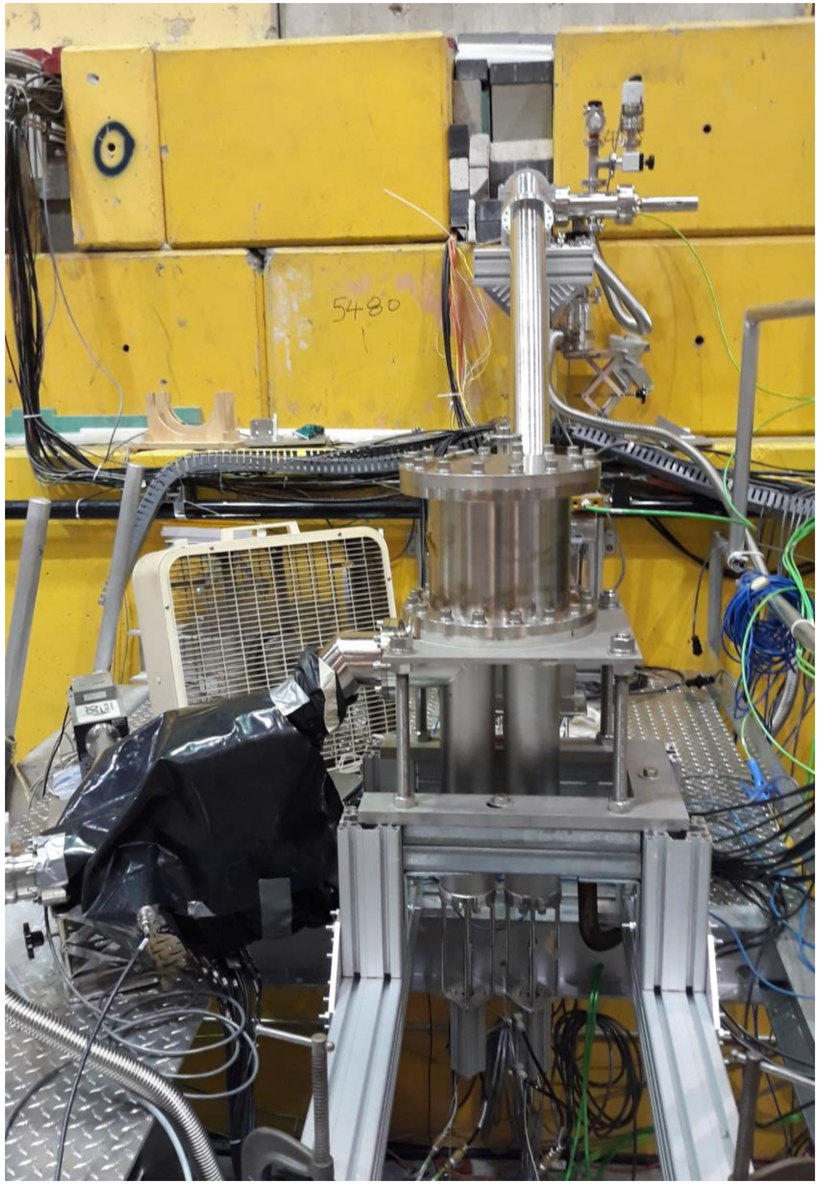
- Transmission 97%
- No excessive UCN losses through slits



Vacuum windows

- 15 µm Ti and 100 µm AlMg3
- Transmission 40% – 50%
- Ti foil withstood accidental 1atm pressure difference

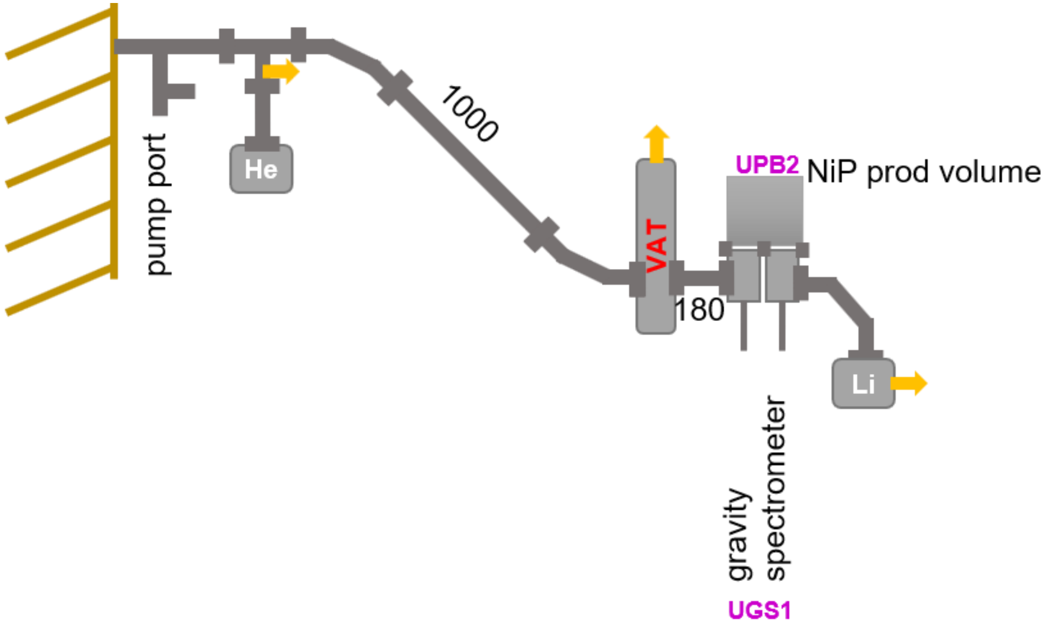
NiP-plated storage volume



Storage lifetime

© Shinsuke Kawasaki

- Before baking: 65 s
- After 12h baking at 100ºC : 75 s
- After 12h baking at 150ºC: 76 s



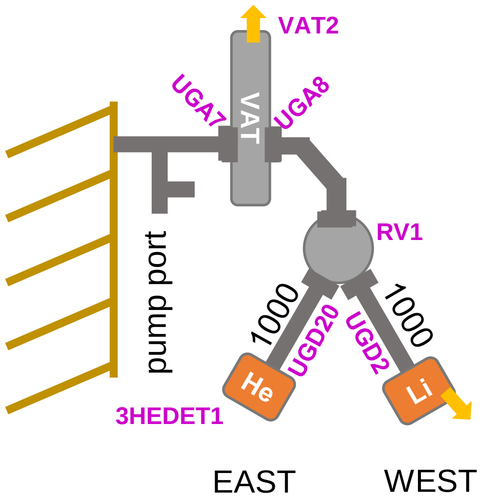
Detectors

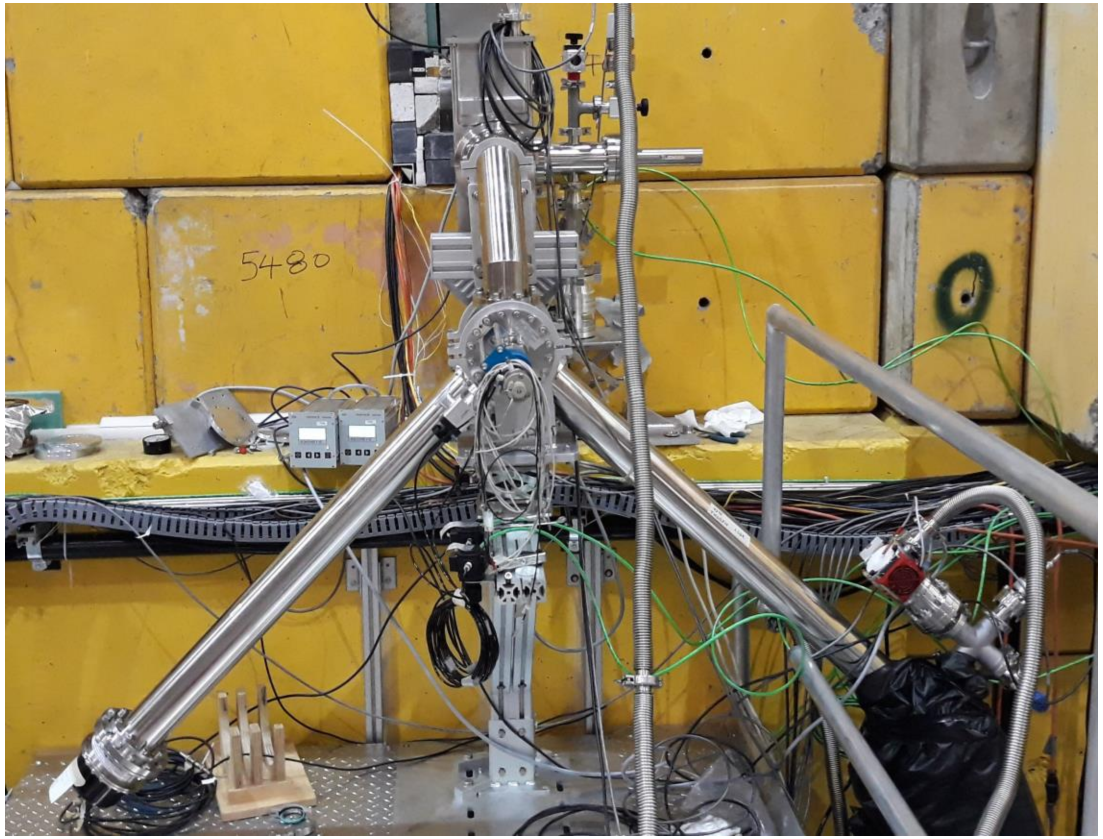
Comparison ^3He to ^6Li

	^3He	^6Li
Background (1/s)	0.035	1.5 – 2.2
Relative efficiency	0.65	1
Light sensitive	No	Yes
Outgassing	No	Yes
Pulse time resolution	~ns	4 ns
Channels	1	9

Made improvements to ^6Li detector
to reduce outgassing and light leakage

Efficiency
© Beryl Bell



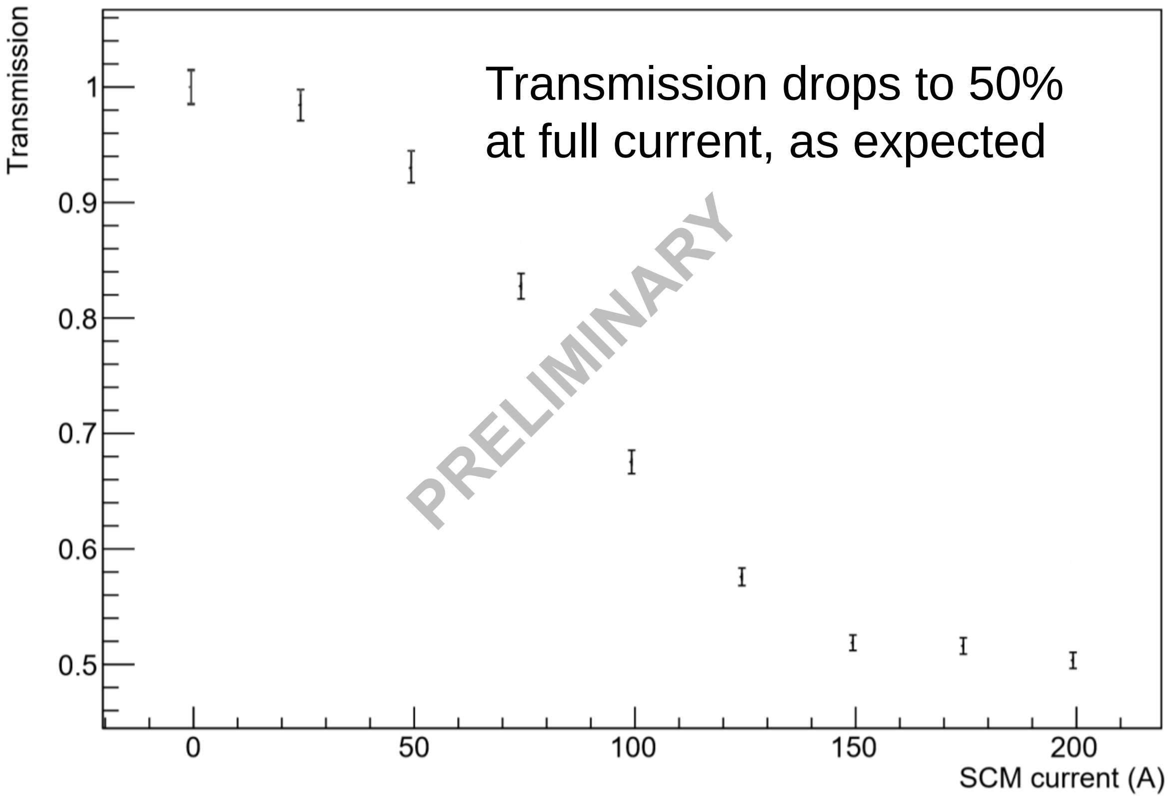


Compared efficiency
with rotary valve

Polarizers and spin flippers

Superconducting polarizer

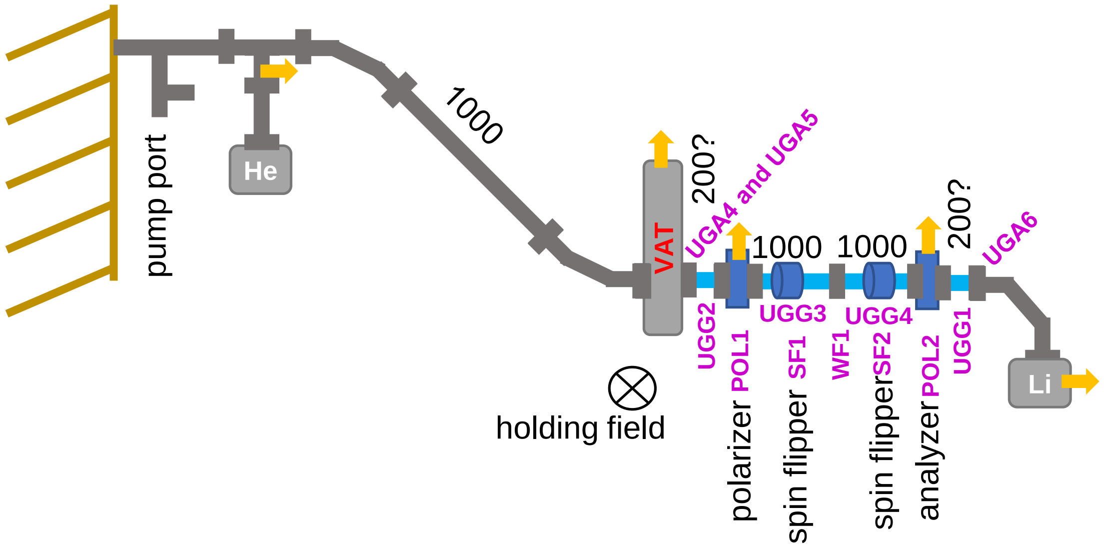
- Added warm bore and vacuum window



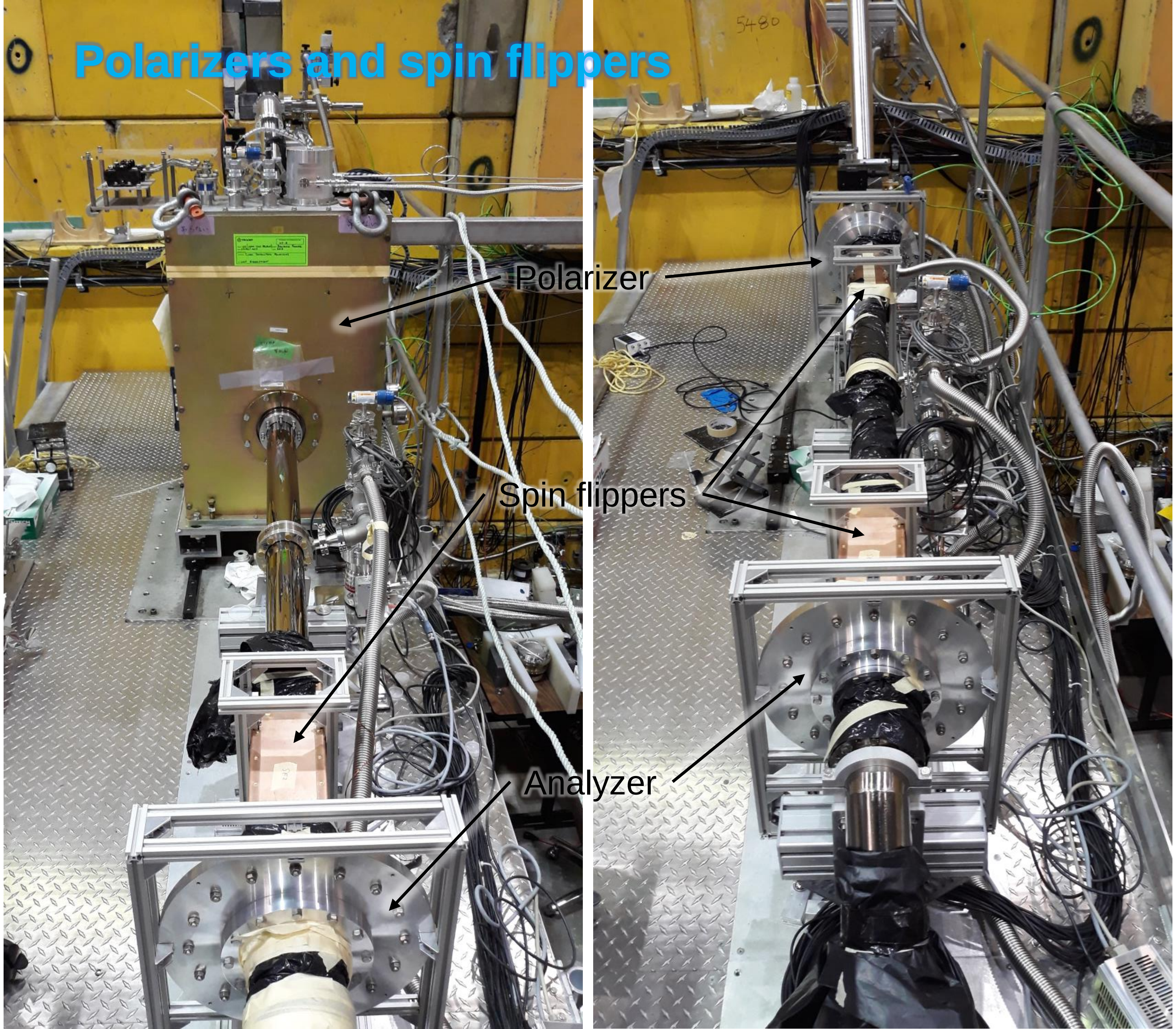
Foil polarizers

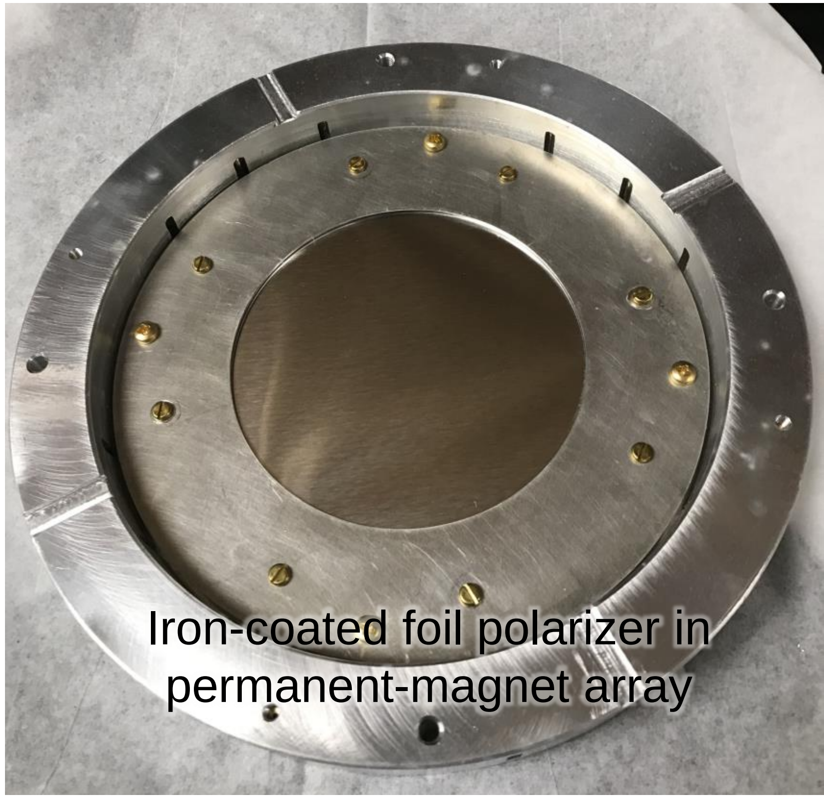
© Sean Hansen-Romu, Blair Jamieson

- Only 60% polarization
- Spin flippers worked well

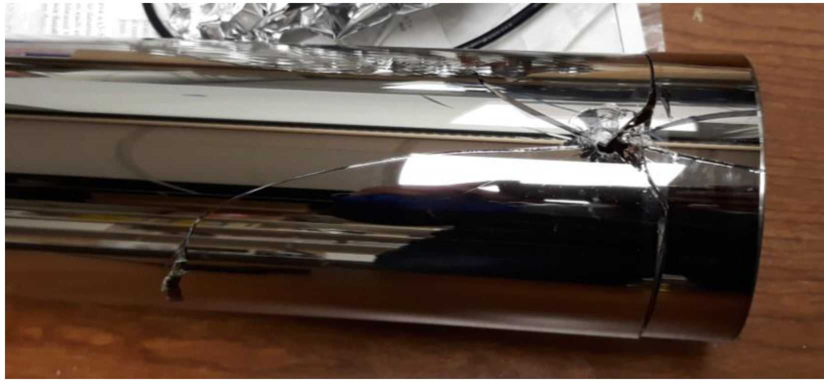


Polarizers and spin flippers





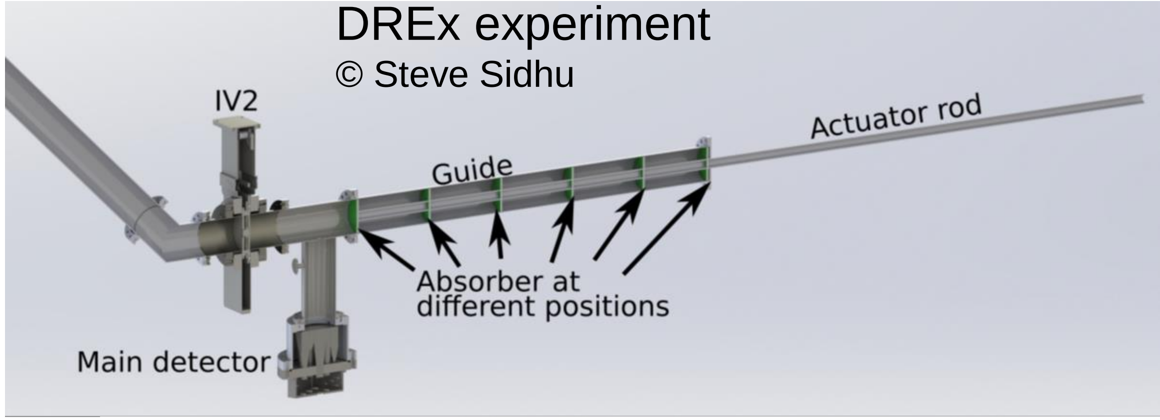
Iron-coated foil polarizer in permanent-magnet array

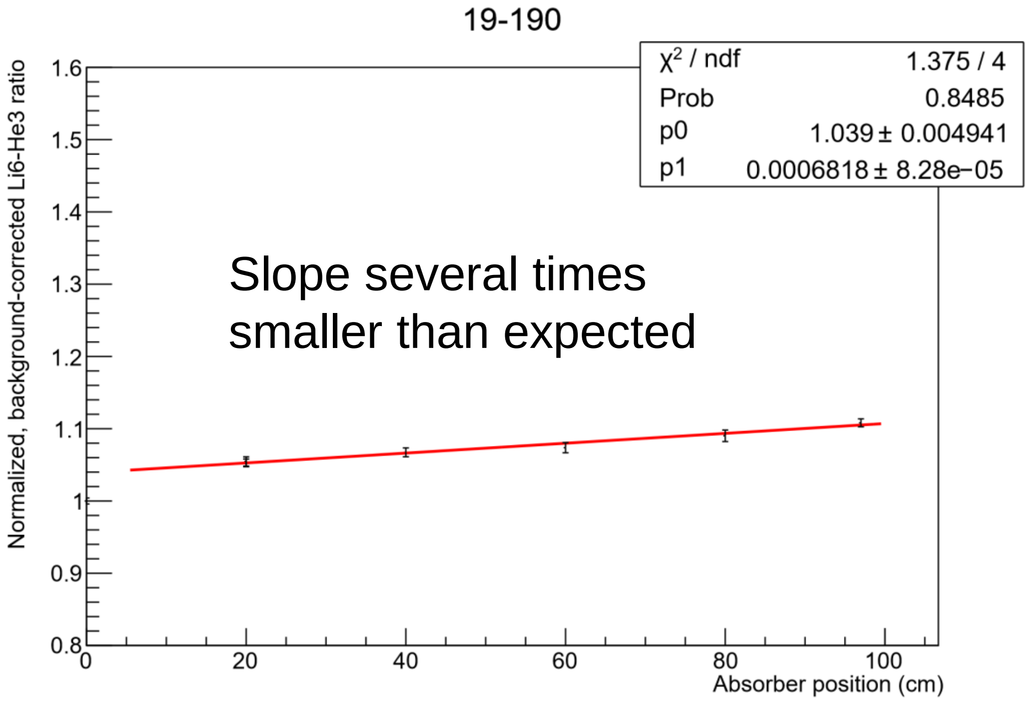


Glass guide broke during disassembly

Analysis in progress

- Understand diffuse reflection experiment "DREx"
  © Steve Sidhu
- Compare transmission and storage-lifetime measurements to simulations
  © Sean Vanbergen
- Compare polarizer measurements to simulations
  © Sean Hansen-Romu
- Measure magnetization of polarizer foils
  © T. Higuchi, F. Piermaier, S. Hansen-Romu, J. Martin
- Develop heat-conduction model
  © Jeff Martin
- Quantify contaminations from residual gas analyses
  © Pietro Giampa, Takashi Higuchi





Conclusions

Important results

- NiP-coated aluminium is suitable for UCN guides (low activation, non-magnetic, cryo tests outstanding)
- Baking temperature 100ºC sufficient
- Overpressure vent, VAT valves, and superconducting polarizer are usable for new source
- Black NiP unsuitable for UCN guide
- Polarizer foils were not fully magnetized

Unfinished experiments (in order of urgency)

1. Thermal-radiation-suppressing guide
2. Transmission of longer guide lengths
3. Comparison of warm-bore diameters for superconducting polarizer
4. Characterizing Y-switch
5. Test flexible guide section
6. Improved foil polarizers
7. Storage in nEDM cell with valve
8. Spin flipper on metallic guide
9. Depolarization on wall bounce

2019 run