UCN 2017 data analysis – comparison with simulations, temperature dependence, and publication

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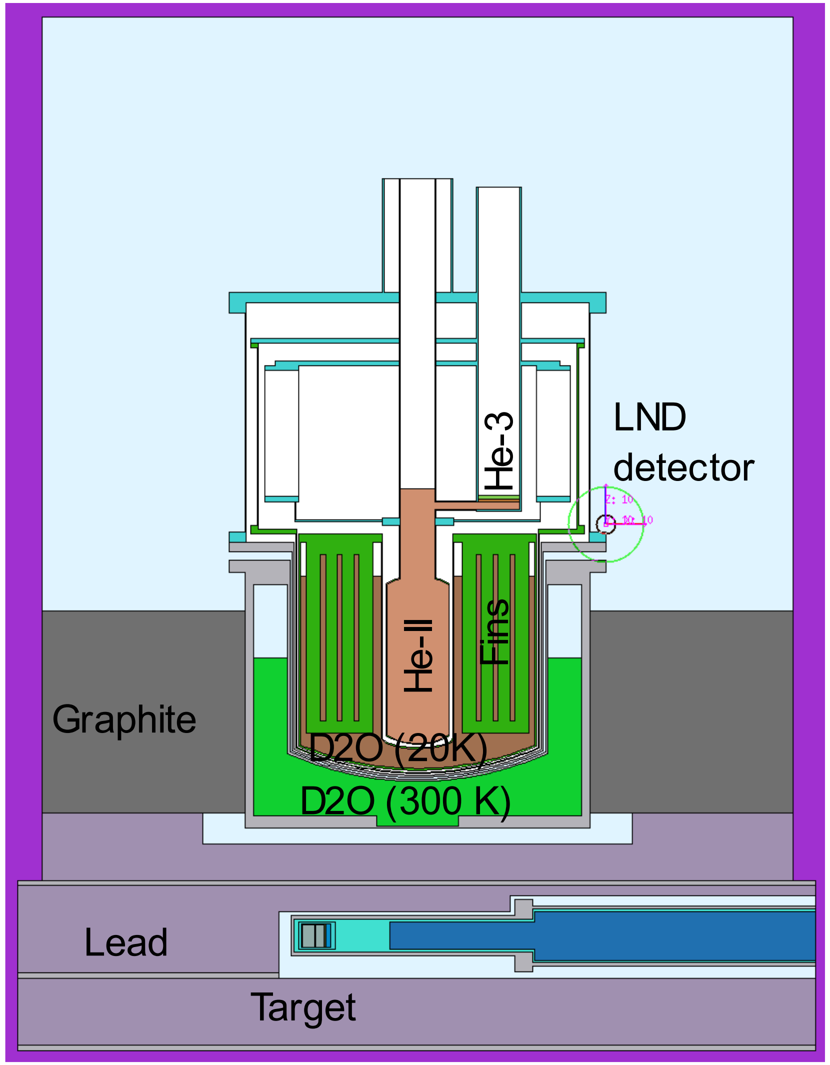
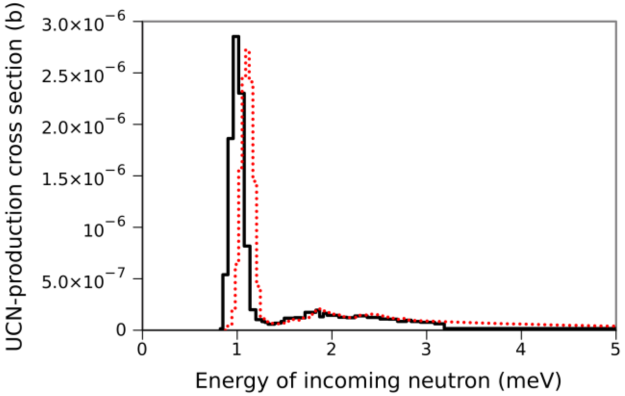
Goals

- Benchmark UCN-production and transport simulations
- Extract temperature-dependence of upscattering in superfluid helium

Simulation models

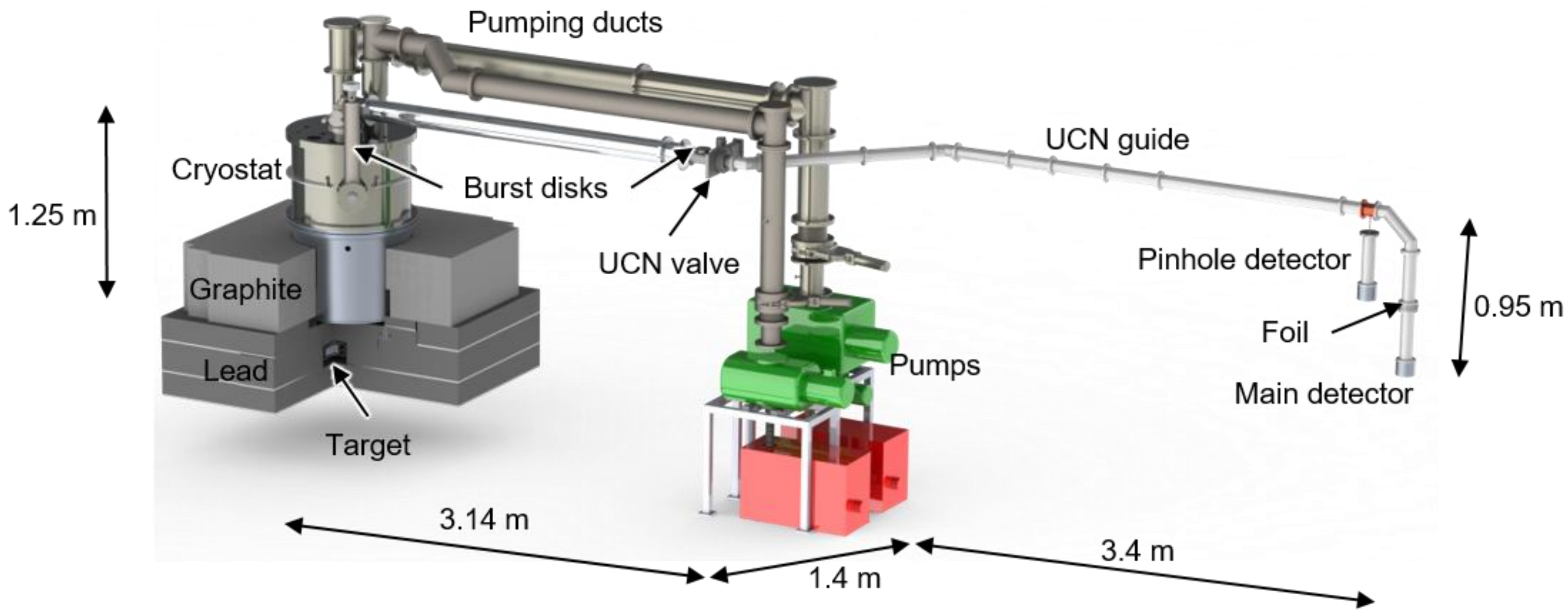


MCNP



- 80 K free-gas model for D2O ice
- UCN production cross sections [1], [2]
- Results at 1 µA:
  - 20600 ± 180 UCN/s below 233.5 neV
  - 12 mW in He-II
  - 12 mW in He-II bottle
  - 49 mW in UCN guide

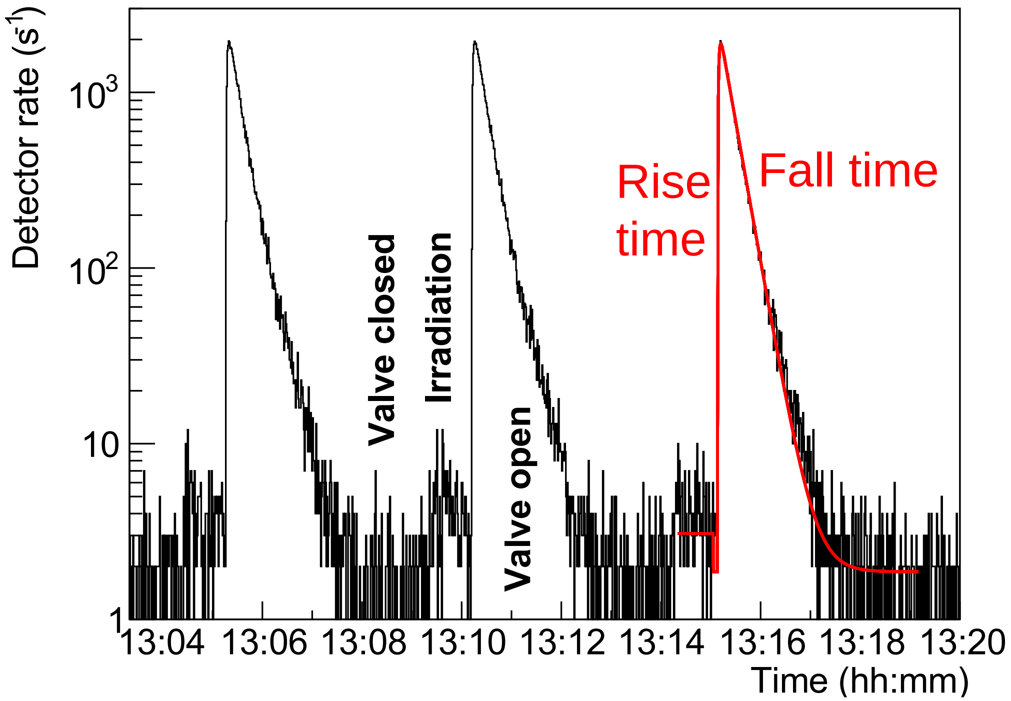
Simulation models



PENTrack

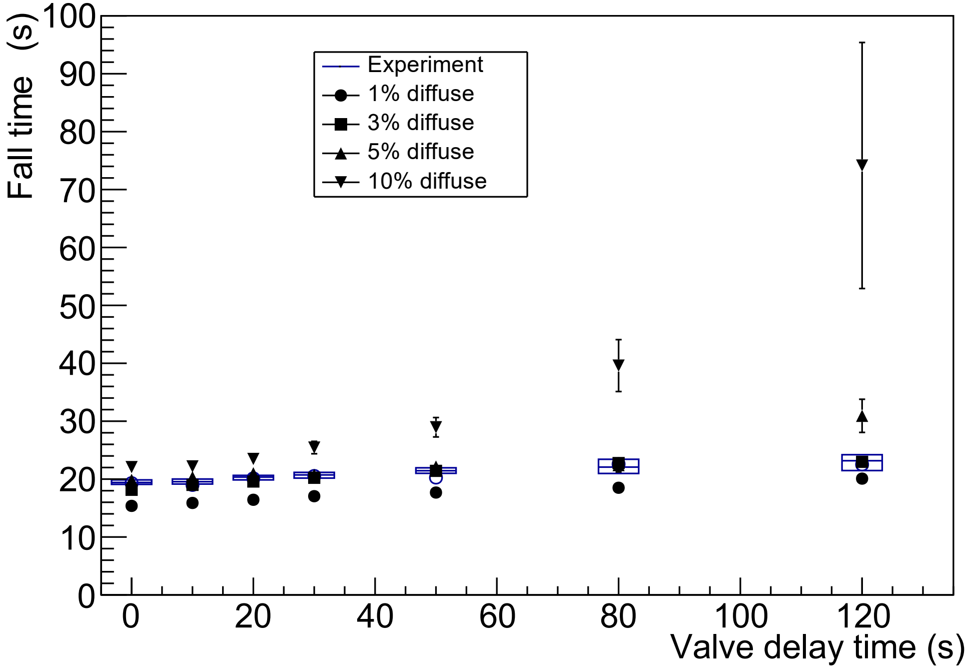
- Storage lifetime in source tuned to 35 s
- He upscattering 390 s (~0.85 K)
- Foil transmission according to PSI measurements
- Detector layers according to [1] and [2]

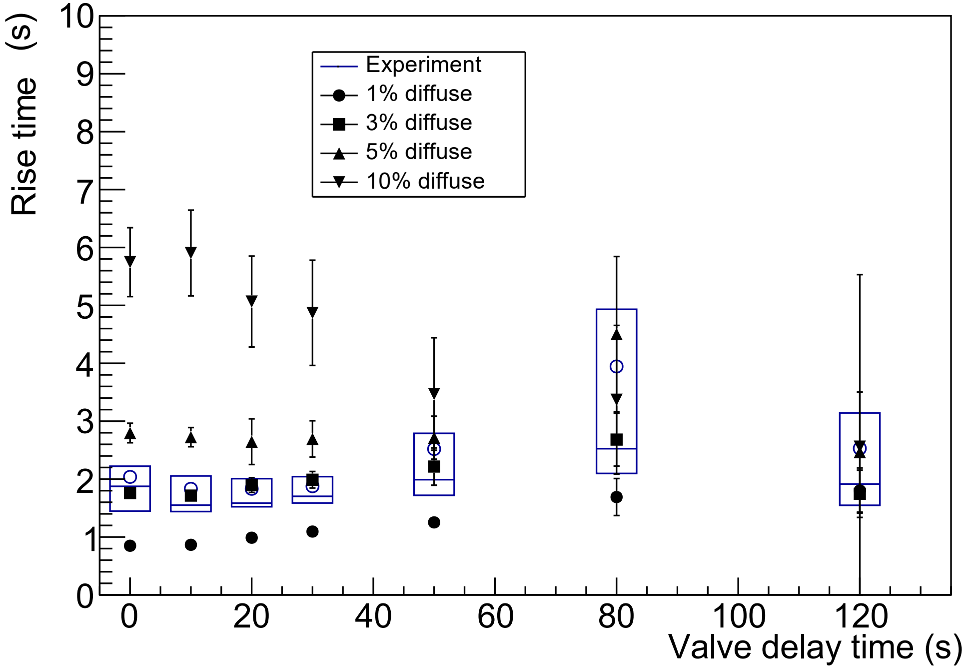
Tuning transport properties



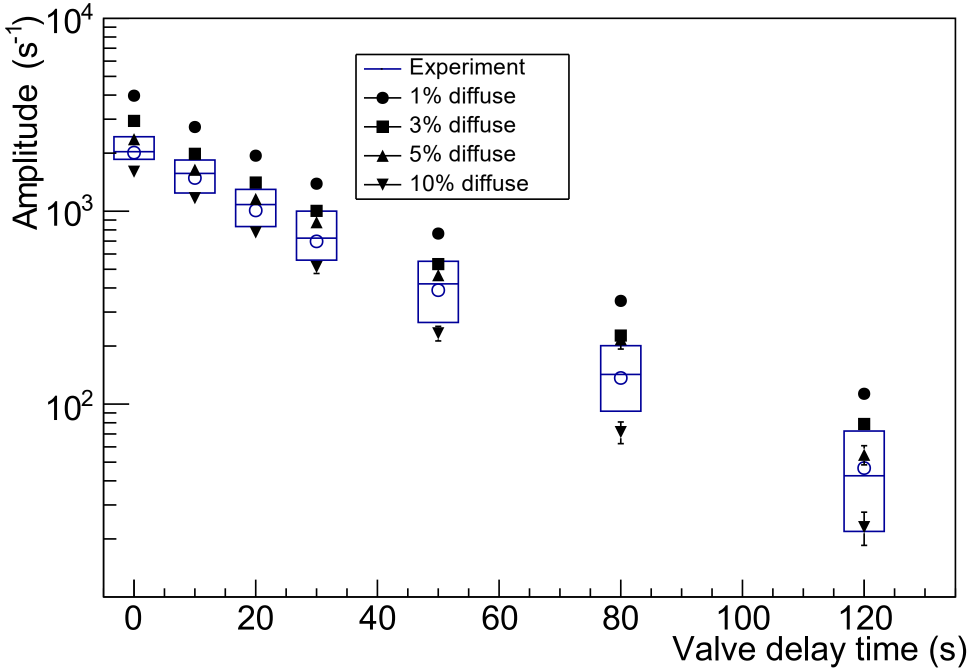
- Fit UCN rate in detector with two exponentials
- Tune diffuse reflection in simulated guides to match time constants

Best agreement with 3% diffuse reflection





UCN yield overestimated by 50%

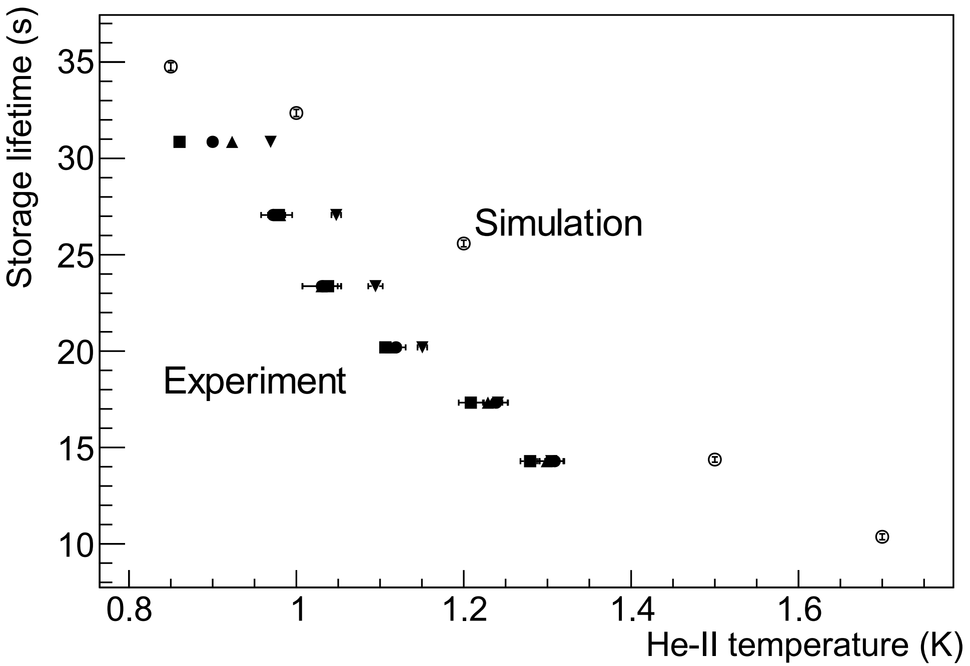


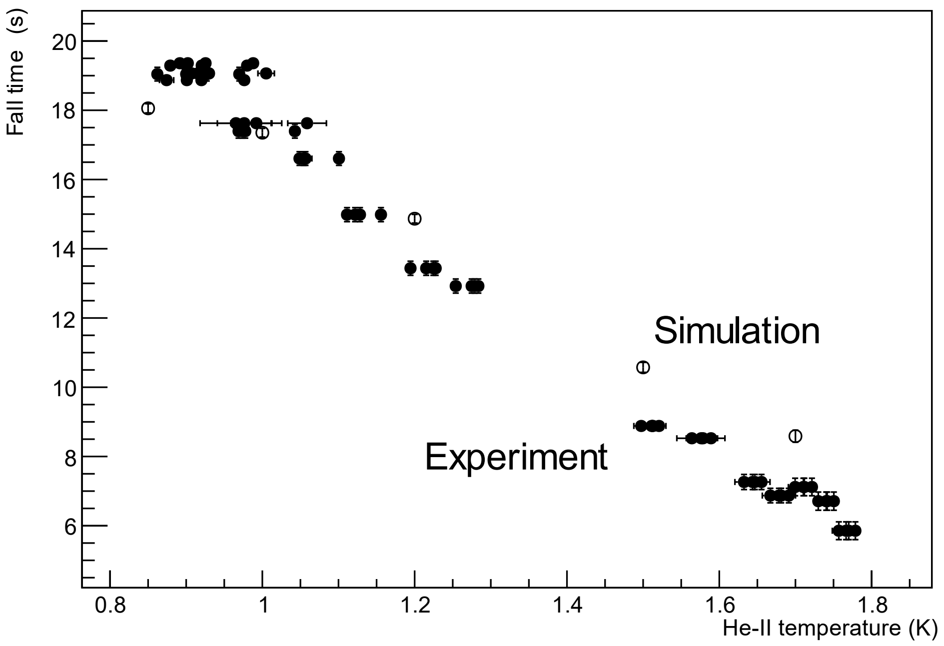
Thermal neutron flux in LND detector

- Measured: $8 \cdot 10^7$ n/cm^2/s
- MCNP: $2.6 \cdot 10^8$ n/cm^2/s

Temperature-dependence:
Experimental storage times drop faster than simulated

Assuming $\tau_{\text{He}}{}^{-1} = 0.008\,\frac{1}{sK^7}\,T^7$

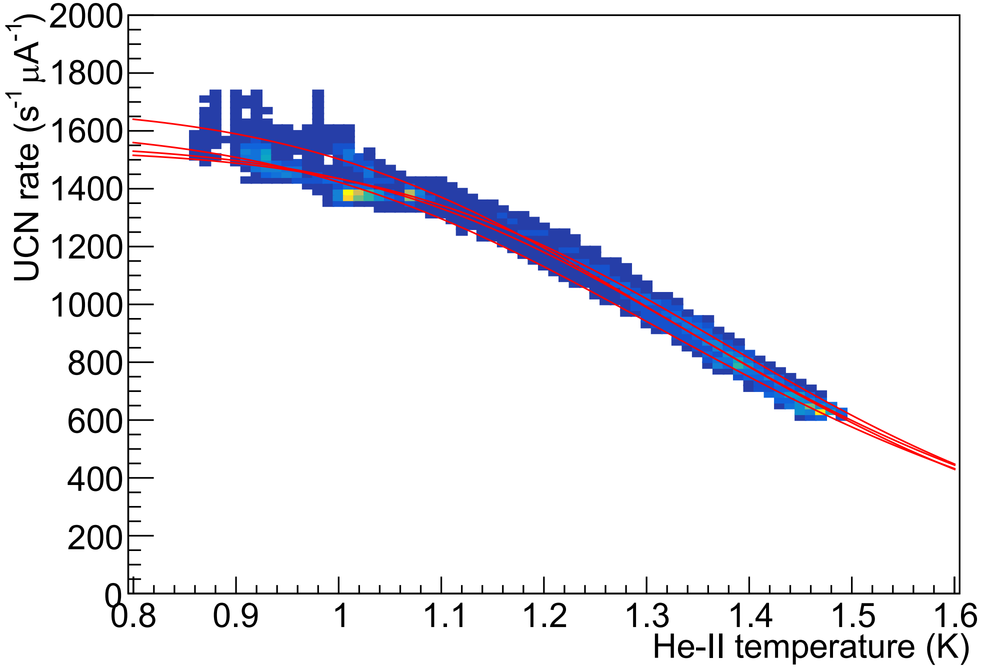




No helium vapor in simulation! Has significant influence at higher temperatures

Temperature dependence

$$\tau_{\mathrm{He}}^{-1} \stackrel{?}{=} B \left(\frac{T}{1\,\mathrm{K}}\right)^a$$



Steady-state measurements

$$R = \frac{P\tau_3}{\tau_d} = \frac{P\tau_d^{-1}}{\tau_{\mathrm{wall},2}^{-1} + \tau_d^{-1} + f_{\mathrm{He},3}\tau_{\mathrm{He}}^{-1}} = \frac{c}{1 + b\left(\frac{T}{1\,\mathrm{K}}\right)^a}$$

$$a = 7.07 \pm 0.02_{\mathrm{stat.}} \pm 0.53_{\mathrm{syst.}}$$

$$b = \frac{f_{\mathrm{He},3}B}{\tau_{\mathrm{wall},2}^{-1} + \tau_d^{-1}} = 0.0978 \pm 0.0007_{\mathrm{stat.}} \pm 0.0290_{\mathrm{syst}}$$

Get $f_{\mathrm{He},3}$ from simulations, $\tau_{\mathrm{wall},2}^{-1} + \tau_d^{-1}$ from fall time

$$B = (10.9 \pm 0.4_{\mathrm{stat.}} \pm 3.4_{\mathrm{syst.}}) \cdot 10^{-3}\,\mathrm{s}^{-1}$$

Good agreement with theory/previous measurements

Publication

Status

- Draft ~75% finished

Plans

- Repeat simulations with helium vapor
- Finish draft until late August
- Upload to arXiv until mid-September!

Thank you!