PAUL SCHERRER INSTITUT

Characterisation of the source for Ultracold Neutrons at the Paul Scherrer Institute

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on behalf of the PSI UCN team

Ultracold Neutrons

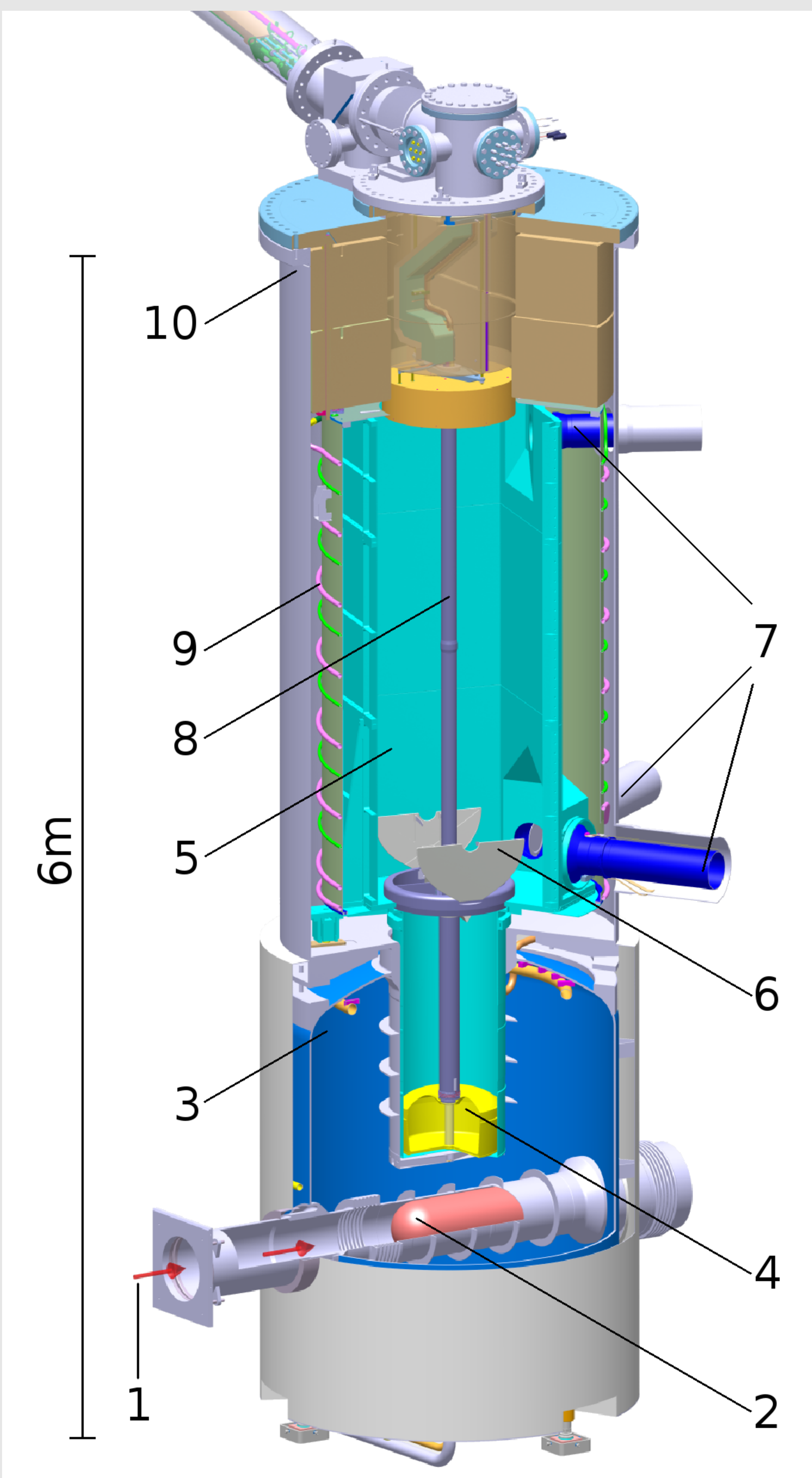
Ultracold:

$E_{kin} < 350\,\mathrm{neV} \Leftrightarrow v < 8\,\mathrm{m\,s^{-1}} \simeq 30\,\mathrm{km\,h^{-1}} \Leftrightarrow \lambda > 140\,\mathrm{nm} \Leftrightarrow T < 4.1\,\mathrm{mK}$

What is the advantage of having neutrons with such low kinetic energies?

Materials with effective wall potentials up to 335 neV (^{58}Ni) exist and allow for storage of ultracold neutrons by total reflection under all angles of incidence. Like this, storage times comparable to the decay time of the free neutron are achievable.
This permits research on free neutrons with long observation times.

The UCN Source



Source Setup:

1. PSI proton beam, up to 8 s pulses @ 2.2 mA
2. spallation target (Pb)
3. D_2O vessel
4. 30 dm^3 solid D_2 moderator
5. ~2 m^3 source UCN storage vessel, coated with diamond-like carbon (DLC)
6. source UCN storage vessel shutter
7. UCN guides towards experiments
   - ~ 8 m long
   - coated with NiMo (85/15)
8. He and D_2 supply lines
9. thermal shield
10. vacuum tank

Design goal:

1000 UCN/cm^3 in a typical external storage volume.

Production of UCN

1. short pulse of 2.2 mA proton beam (E = 590 MeV) on lead target
2. neutrons produced by spallation ($\overline{E}_{kin} \simeq 2$ MeV)
3. thermal moderation in D_2O ($\overline{E}_{kin} \simeq 25$ meV)
4. further moderation to cold Neutrons in the solid deuterium moderator ($\overline{E}_{kin} \simeq 10$ meV)
5. downscattering to kinetic energies below 350 neV in the solid deuterium moderator. UCN from the upper part can escape the deuterium
6. storage of ultracold neutrons 1.25 m above deuterium moderator
7. distribution of UCN to experiments through neutron guides

Status

- commissioning completed: 2010
- first protons on target: Dec 2010
- operation approval: June 2011
- first beam: August 2011
- since 2012: In routine operation
- 2014: Starting, expect operation in August

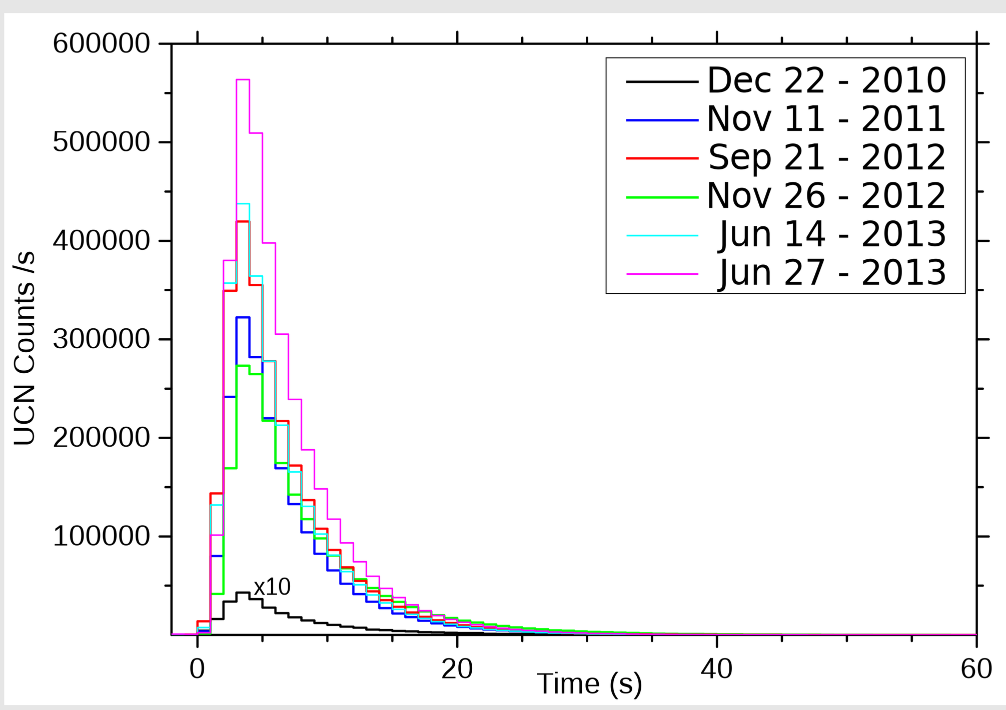
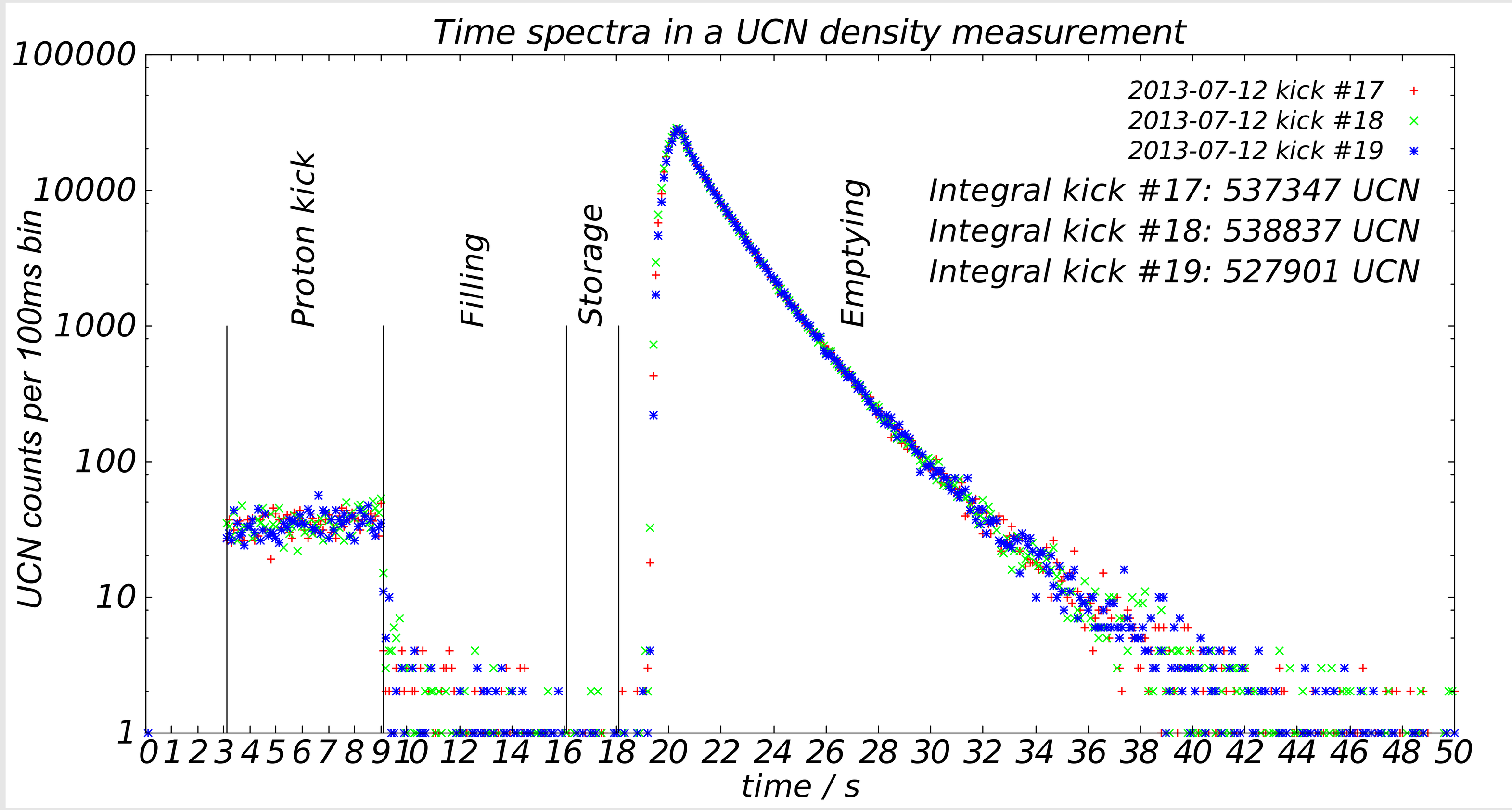


Figure: Evolution of UCN output of benchmark 2 s proton beam kicks, source storage vessel shutter open

UCN density measurement

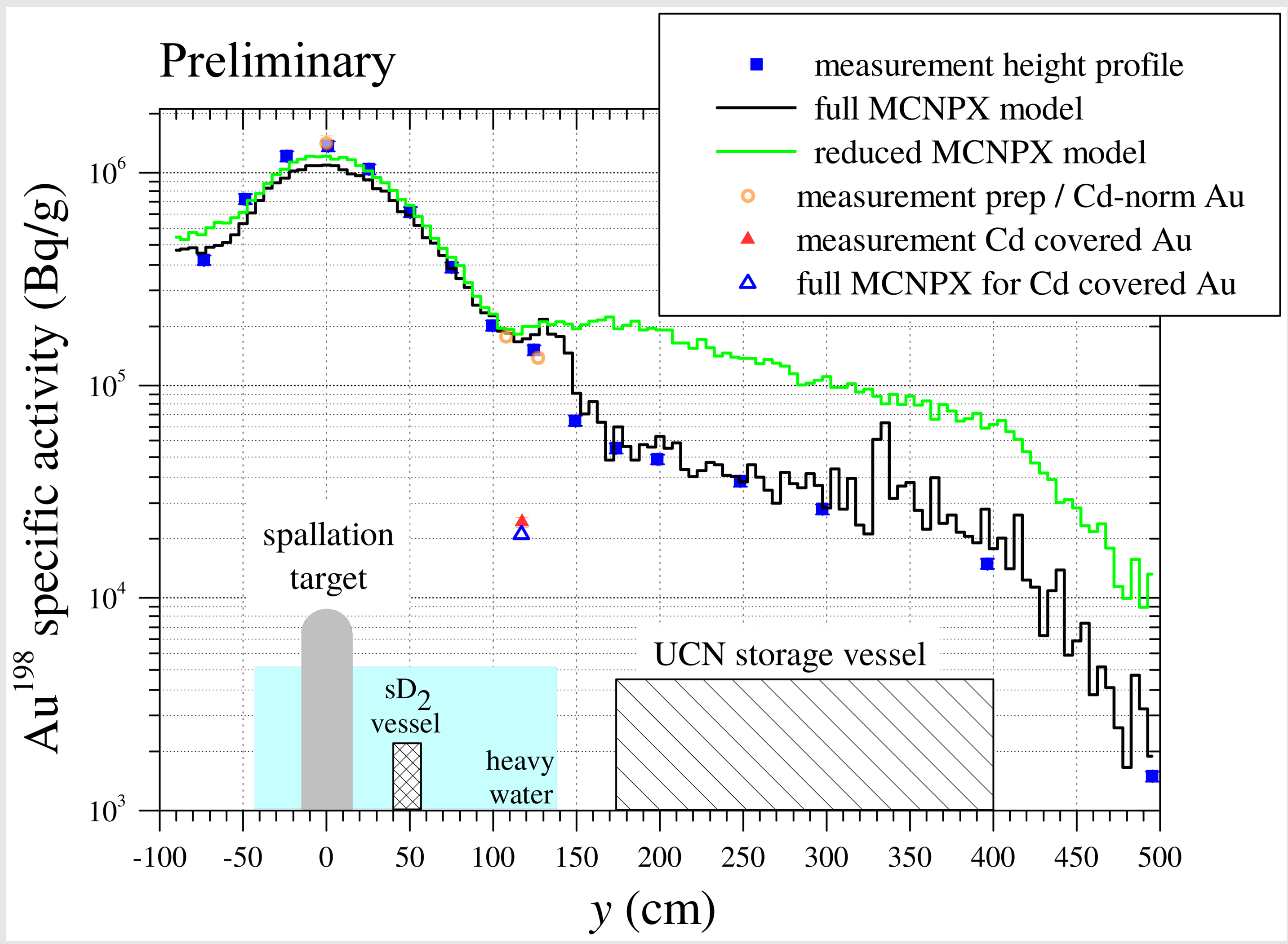
- 25 L UCN storage bottle attached to beam port "West 1"
- 6 s proton beam kick on target
- fill bottle, close, empty into detector



A density of 30 UCN/cm^3 was measured, taking into account transmission losses of the detector window. This places the UCN source at PSI among the best performing UCN sources in the world.

Thermal Neutron Flux Characterisation - Preliminary

- thin gold foils were placed along the vacuum tank
- irradiation for 2 s of proton beam on target
- $^{197}\mathrm{Au} + n \rightarrow {}^{198}\mathrm{Au} \rightarrow {}^{198}\mathrm{Hg} + e^- + \gamma$
- measurement of the specific activity of the foils using Germanium detectors
- comparison to MCNPX Monte Carlo calculations



Measurement and simulation agree, which shows that the production of thermal neutrons in the target and D_2O moderator assembly are well understood.

UCN Transport through Guides and Source Storage Vessel

- store UCN at the end of one guide
- empty internal storage volume completely
- release the UCN towards the source
- detect UCN at the end of the second guide

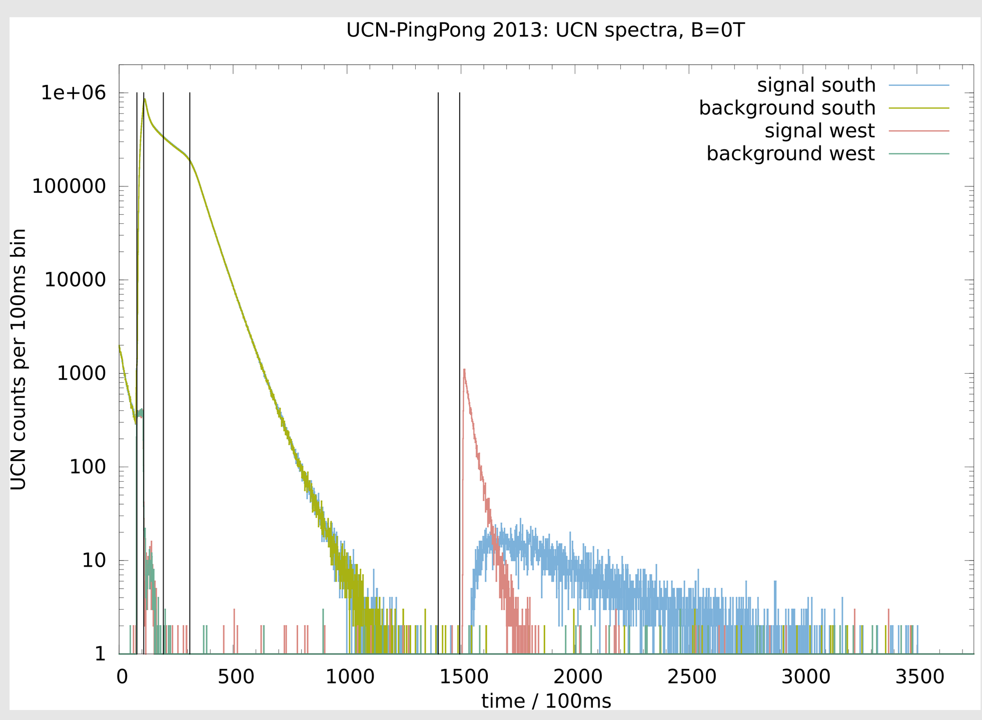


Figure: Time spectrum of a transport measurement

Acknowledgements

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