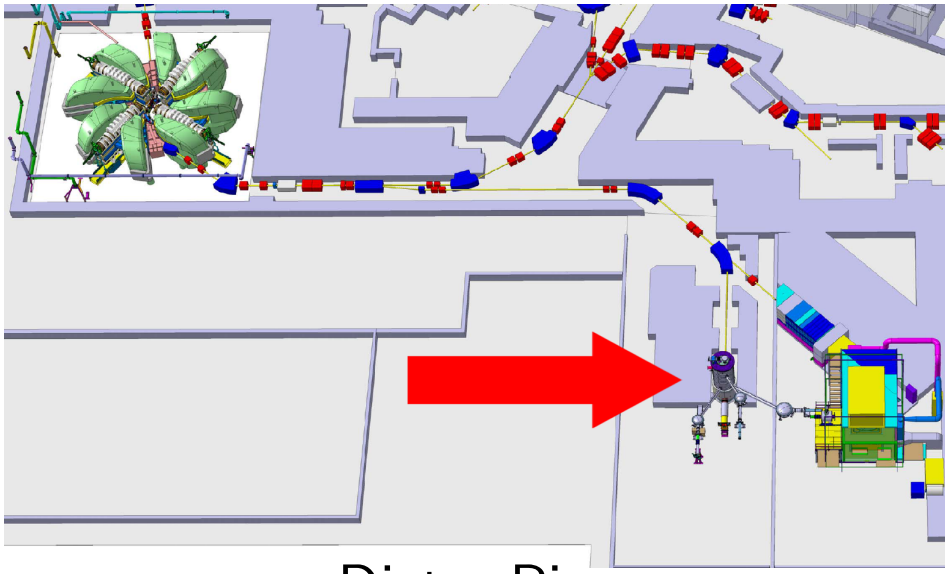
Status of the source for ultracold neutrons at the Paul Scherrer Institute

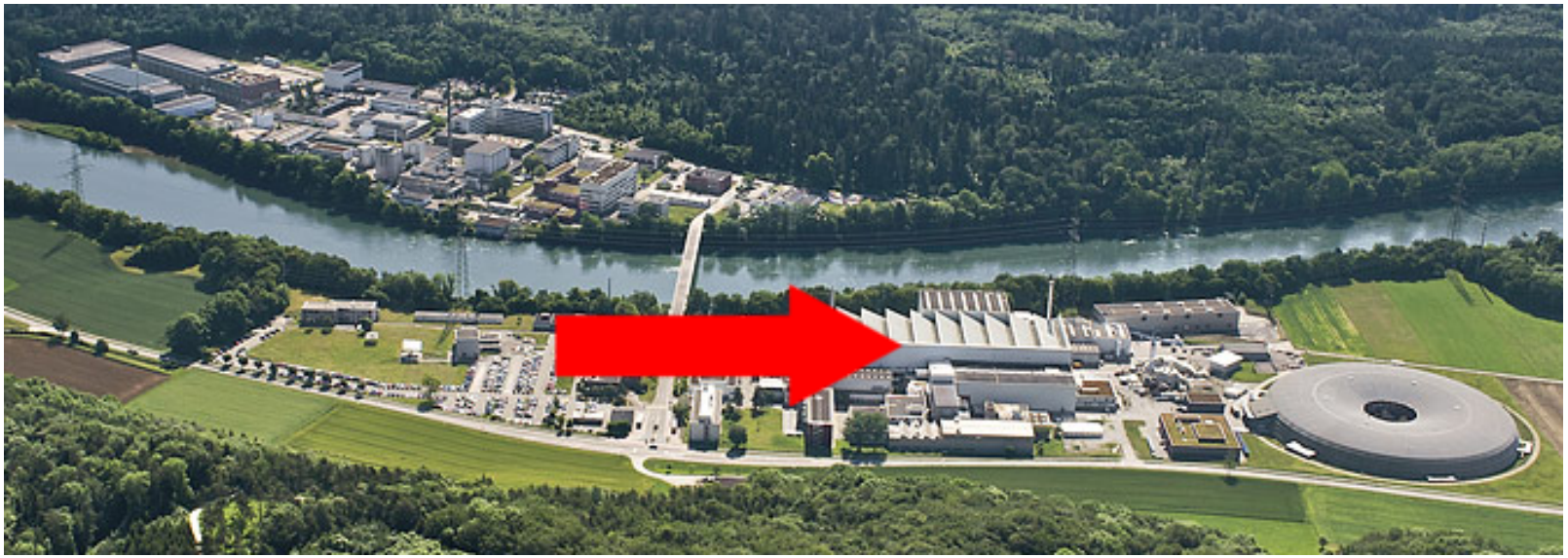


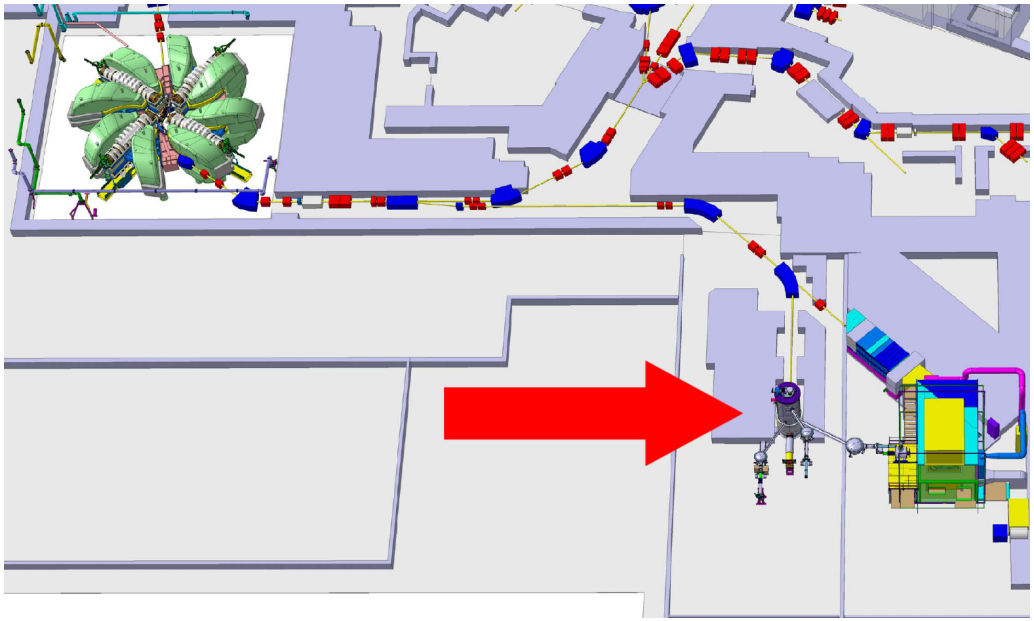
Dieter Ries
on behalf of the PSI UCN project team

PSI2013

September 10, 2013

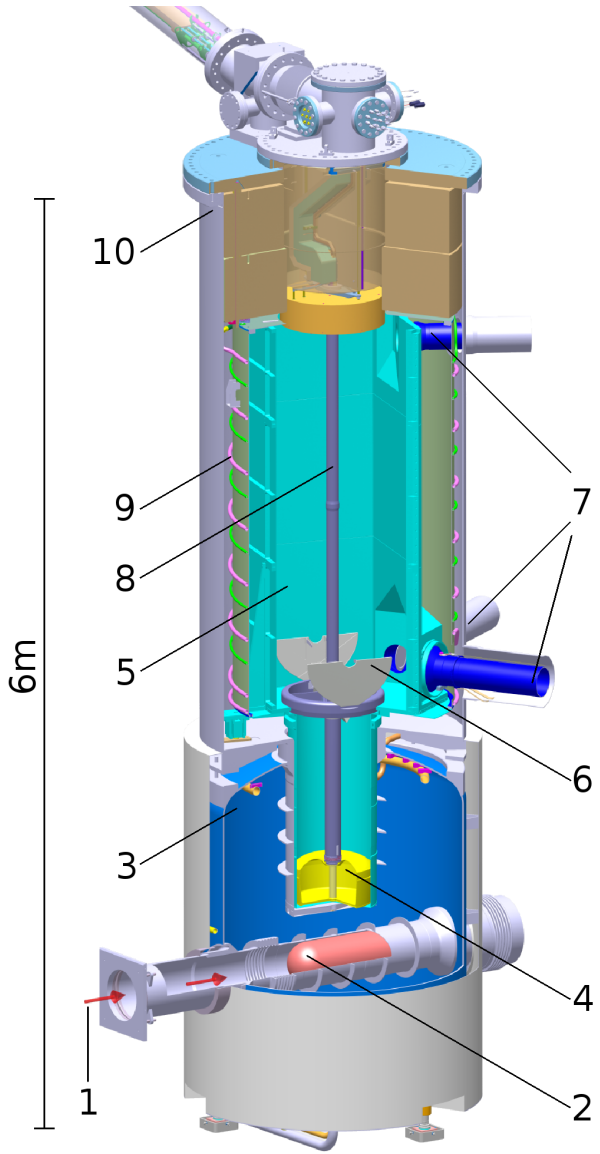
Location





- Paul Scherrer Institut
- 590 MeV proton accelerator
- 2.2 mA beam current
- 1 % dutycycle

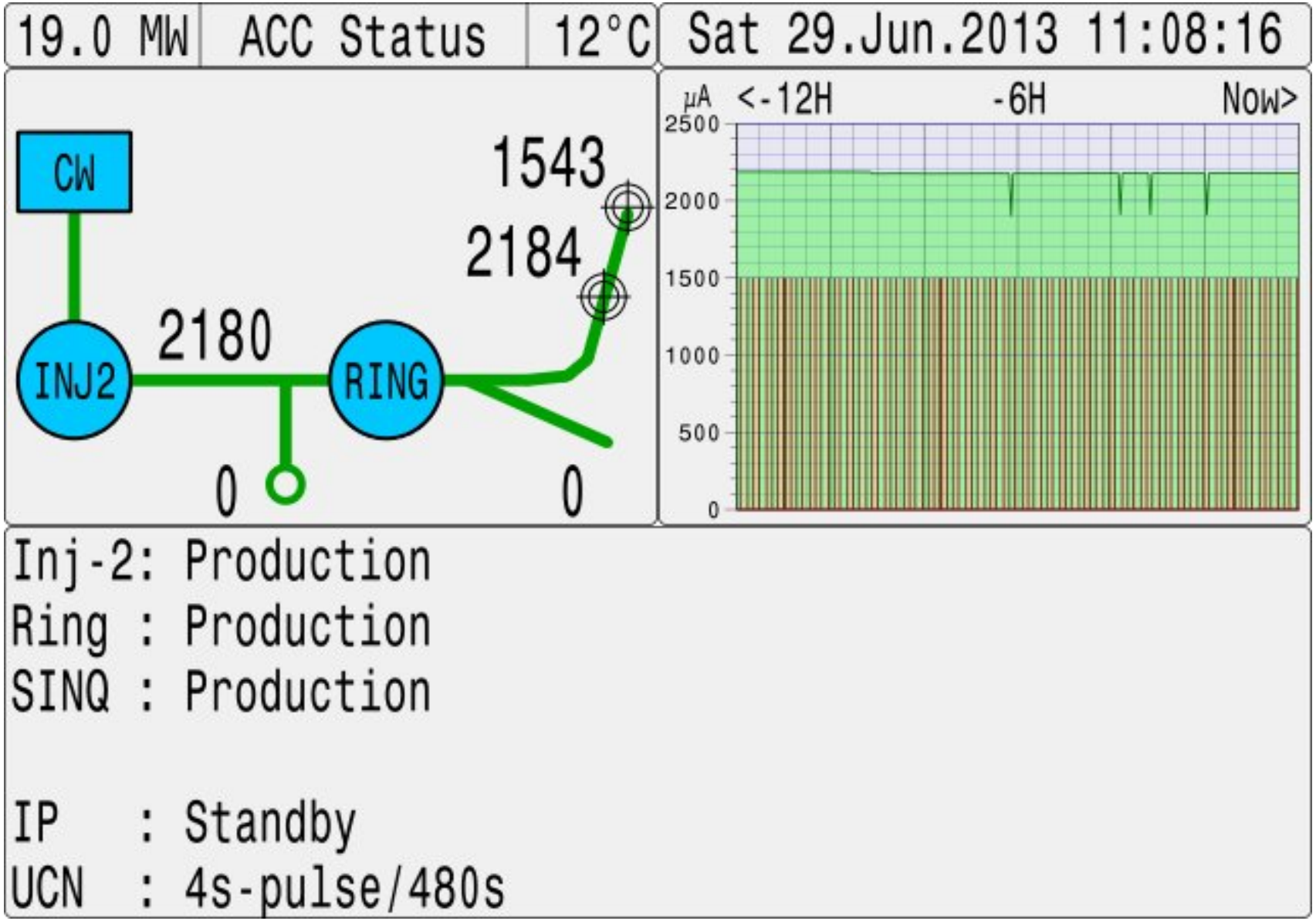
The UCN source at PSI



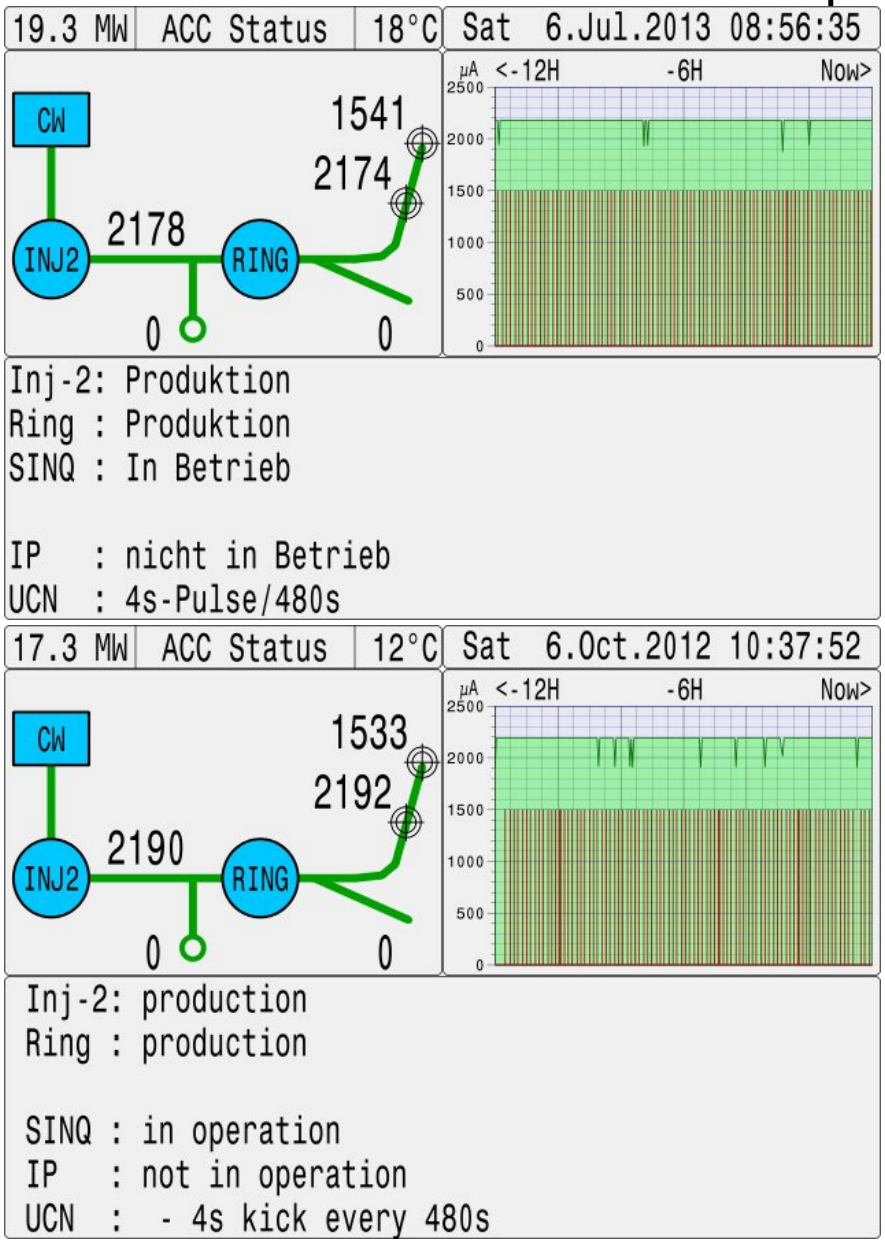
1. PSI proton beam, up to 8 s pulses
2. Spallation target (Pb)
3. D_2O vessel
4. 30 dm^3 solid D_2 moderator, coated with DLC.
5. $\sim$2 m^3 UCN storage vessel
6. Storage vessel shutter
7. UCN guides towards experiments, $\sim$ 8 m long, coated with NiMo
8. He and D_2 supply
9. Thermal shield
10. Vacuum tank

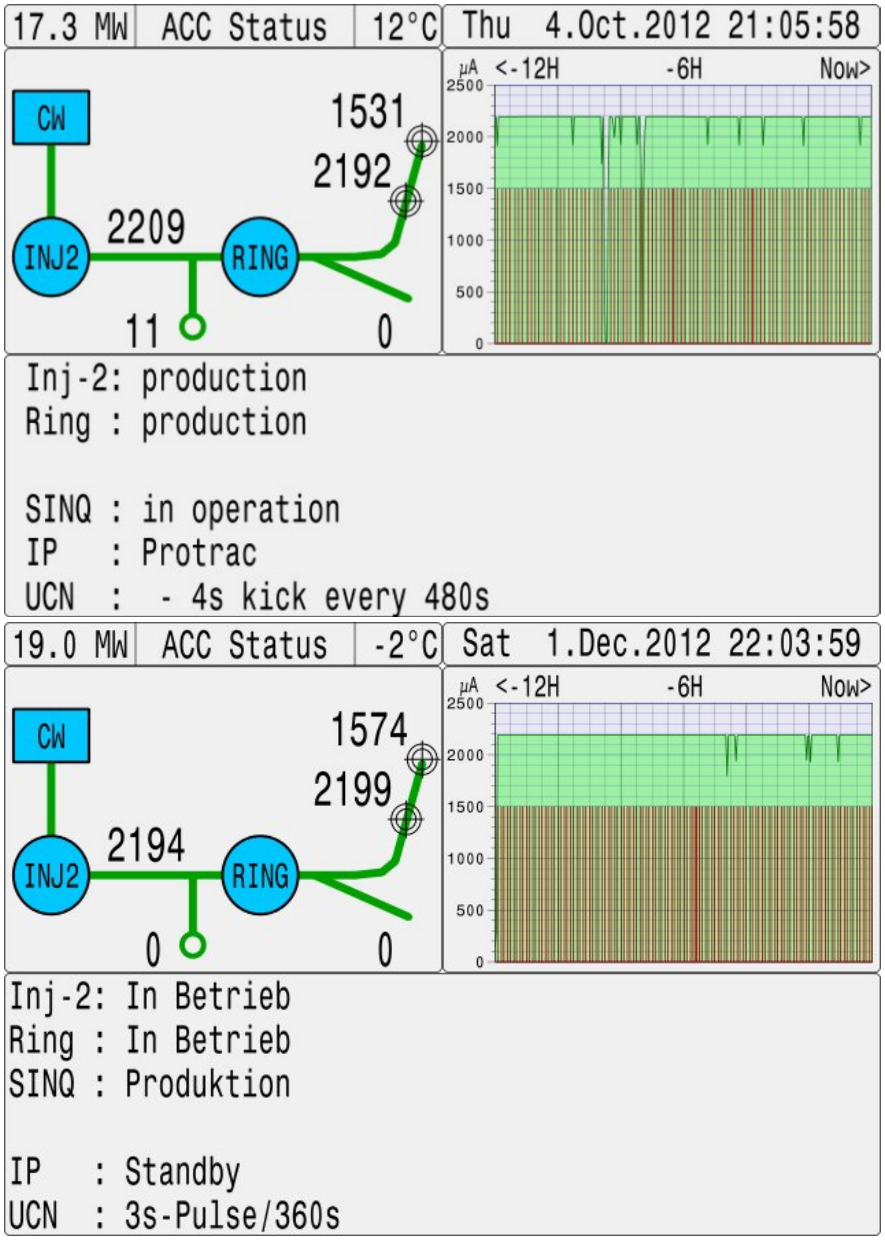
Design goal: 1000 UCN/cm^3 in a typical external storage volume.

In regular operation since 2012



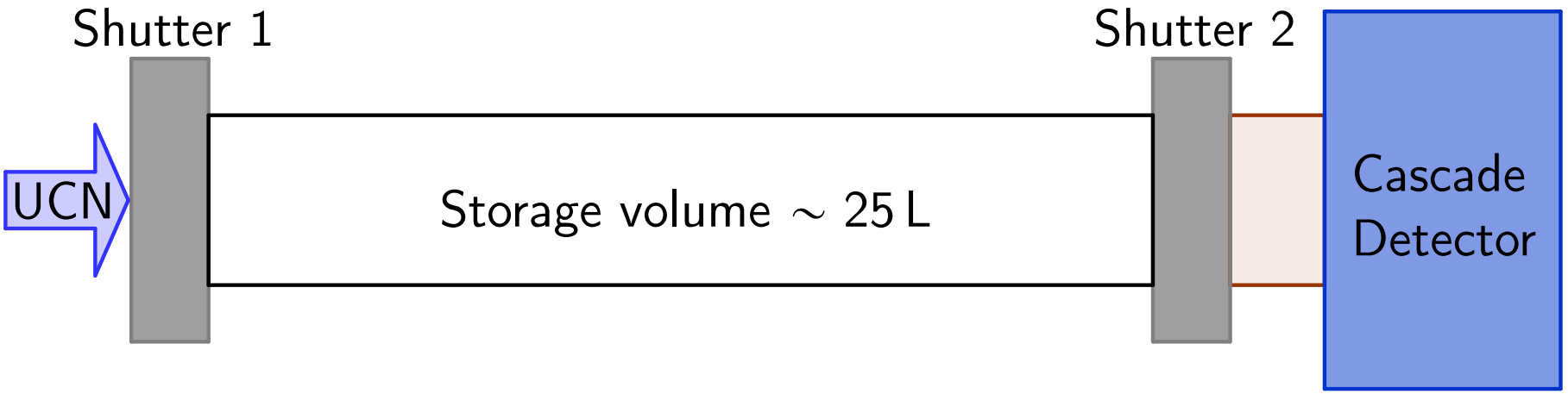
in operation 2



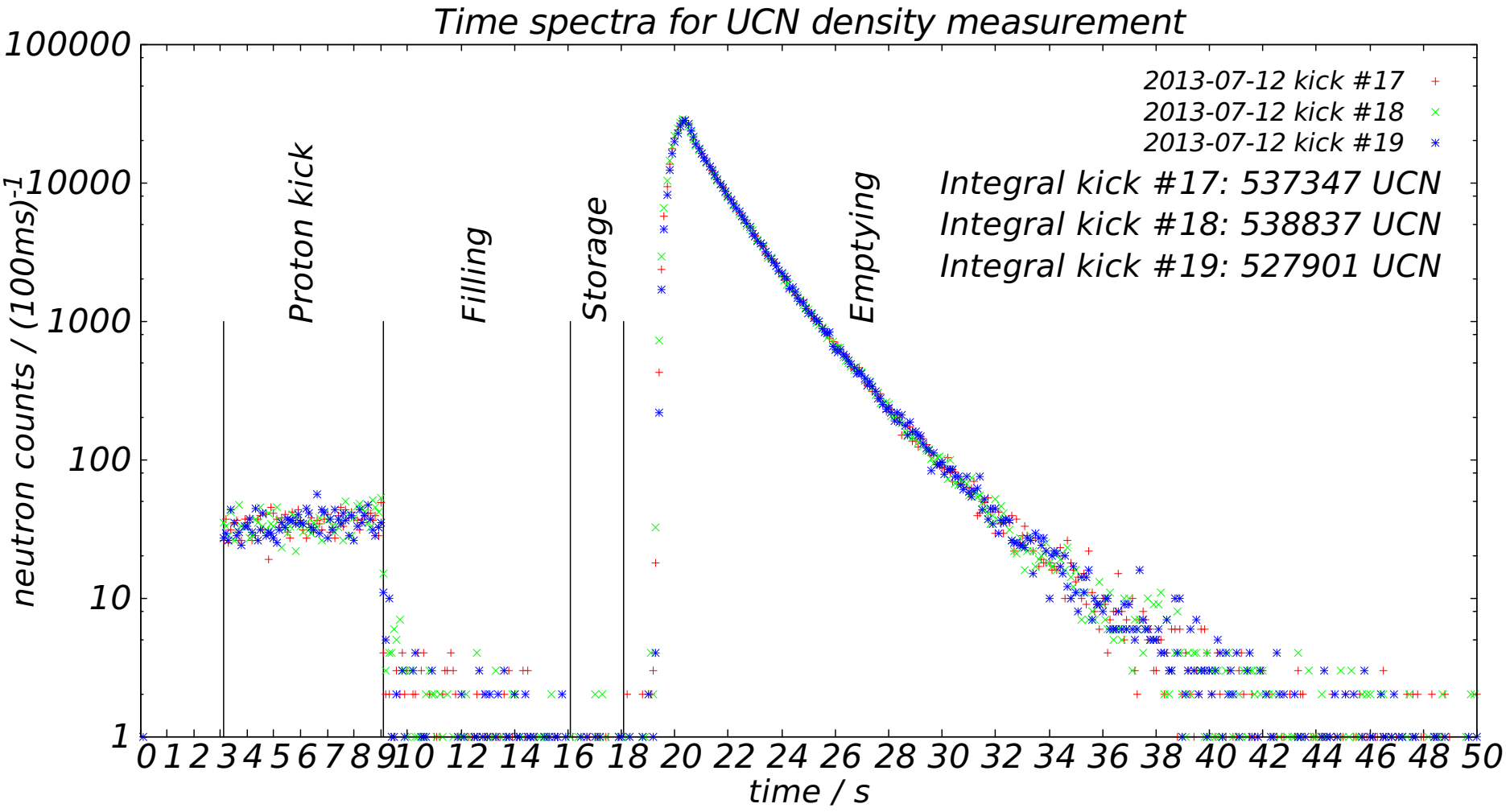


Measurement of the UCN Density 1

- Measured in July 2013 at the west-1 beamport of the UCN source.
- Storage volume: 1 m long glass tube, inside diameter 180 mm.
- Wall coating: 500 nm NiMo, optical potential $\sim$ 220 neV.
- Shutter coating: Diamond like carbon, optical potential $\sim$ 230 neV.



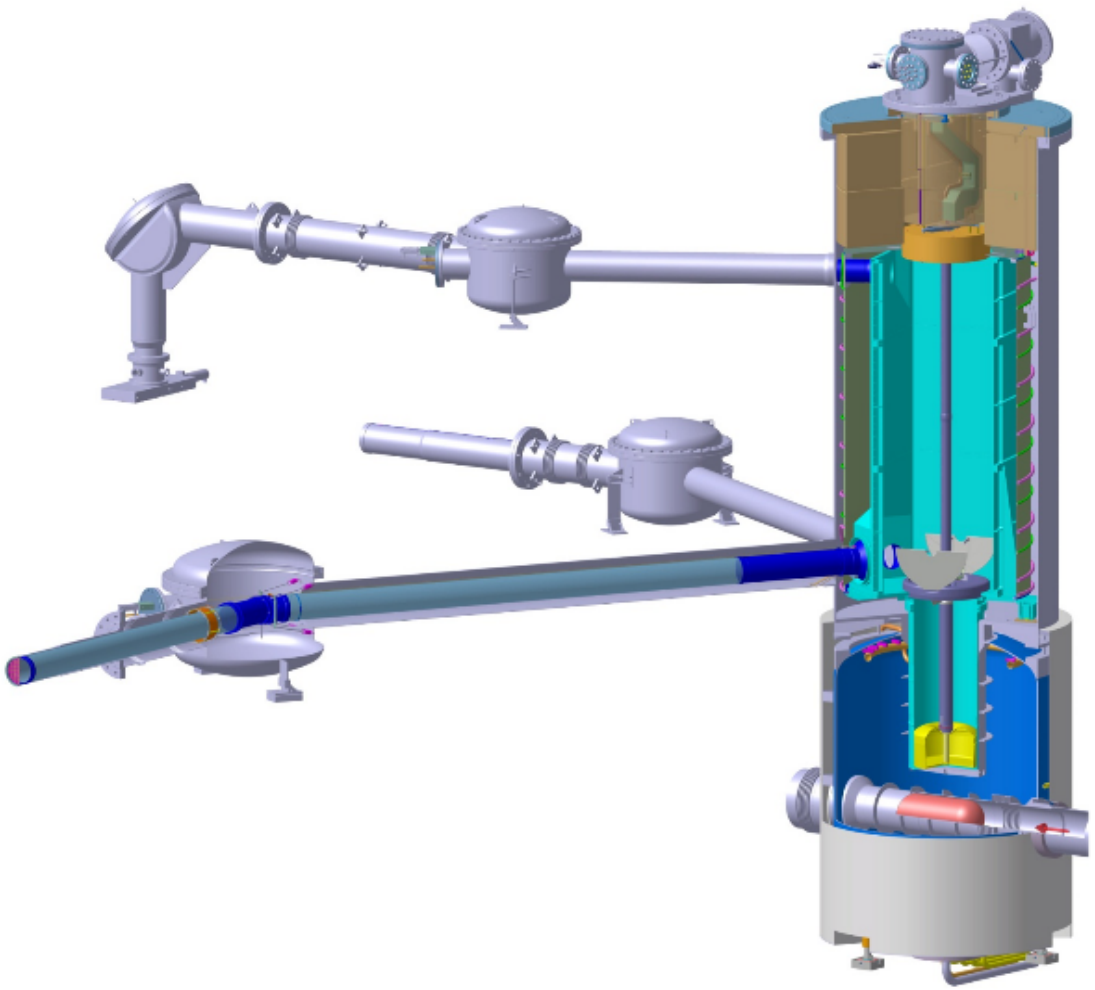
Measurement of the UCN Density 2



Measurement of the UCN Density 3

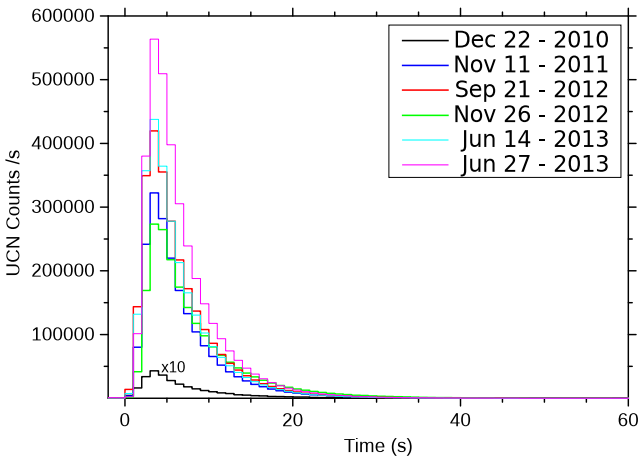
- Storage volume: 25 447 cm^3.
- Measured 21.0(2) UCN/cm^3 after 2 s storage.
- Transmission of $\mathrm{AlMg3}$ detector entrance window: $\lesssim$ 70 %.
- Total UCN density at beamport: 30 UCN/cm^3 after 2 s storage.

Understanding and improving UCN performance



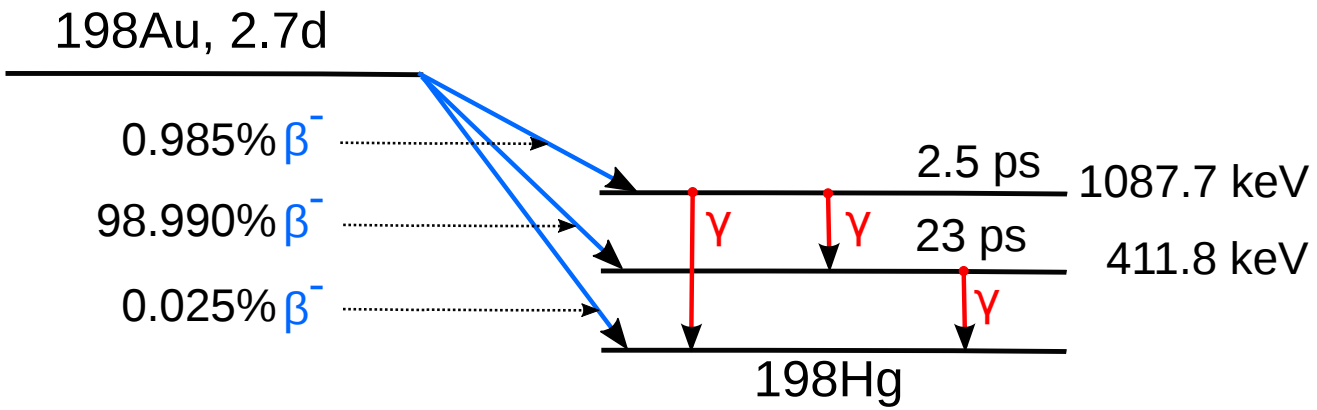
Approach:

- measure performance of each subsystem
- verify model predictions
- exclude neutron loss



Gold activation measurements

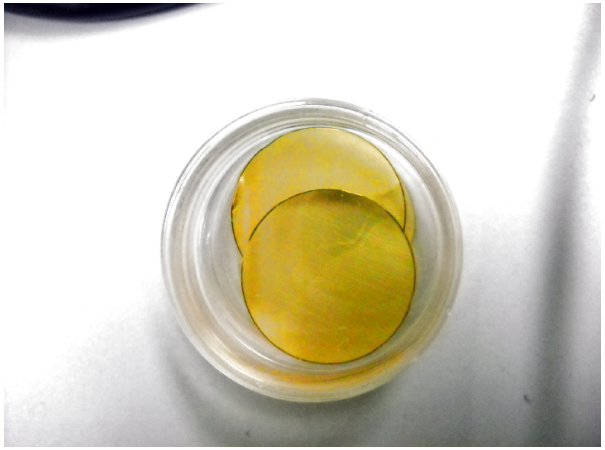
- Well known technique to measure thermal neutron fluxes.
- Neutron capture: $^{197}\mathrm{Au} + n \rightarrow {}^{198}\mathrm{Au}$.
- Subsequent beta decay, $\tau \simeq 2.7\,\mathrm{d}$.



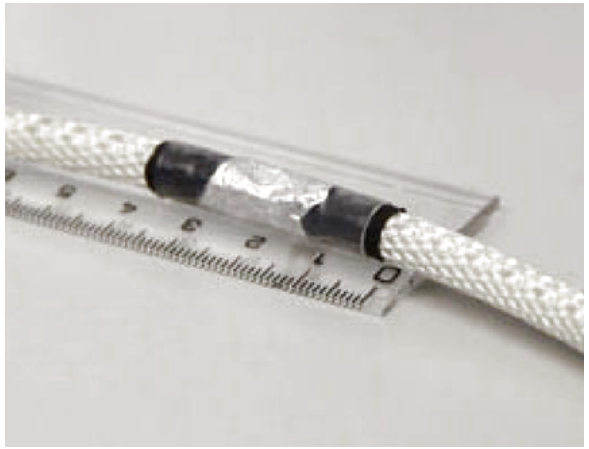
- Gamma spectroscopy used to determine initial activation.
- Derive flux of neutrons through foil from activation, foil mass, expected neutron energy spectrum.

Gold activation measurements 2

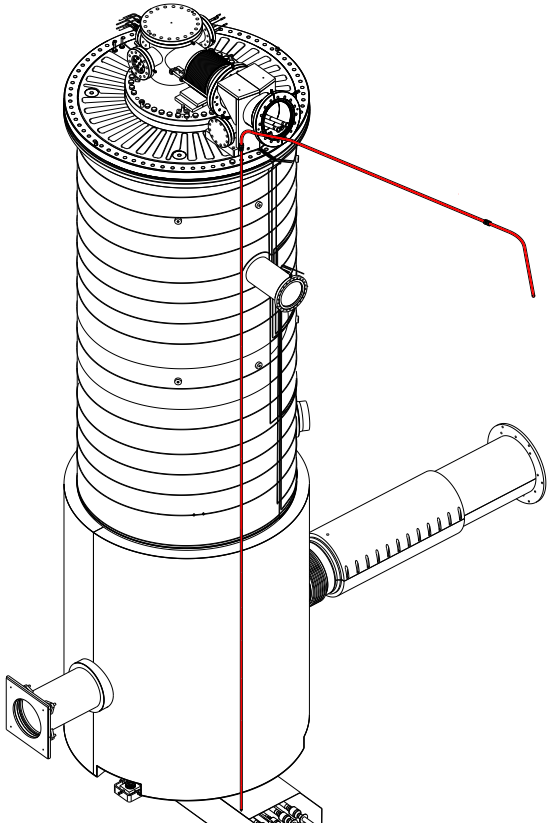
- 16 Au foils, 25 µm thick, in vertical tube along vacuum tank.
- Irradiated during one 2 s proton beam kick.
- Standard foil geometry, circular, radius 12.5 mm, calibrated solid angle in detector.
- Mass: $\mathcal{O}(250\,\mathrm{mg})$



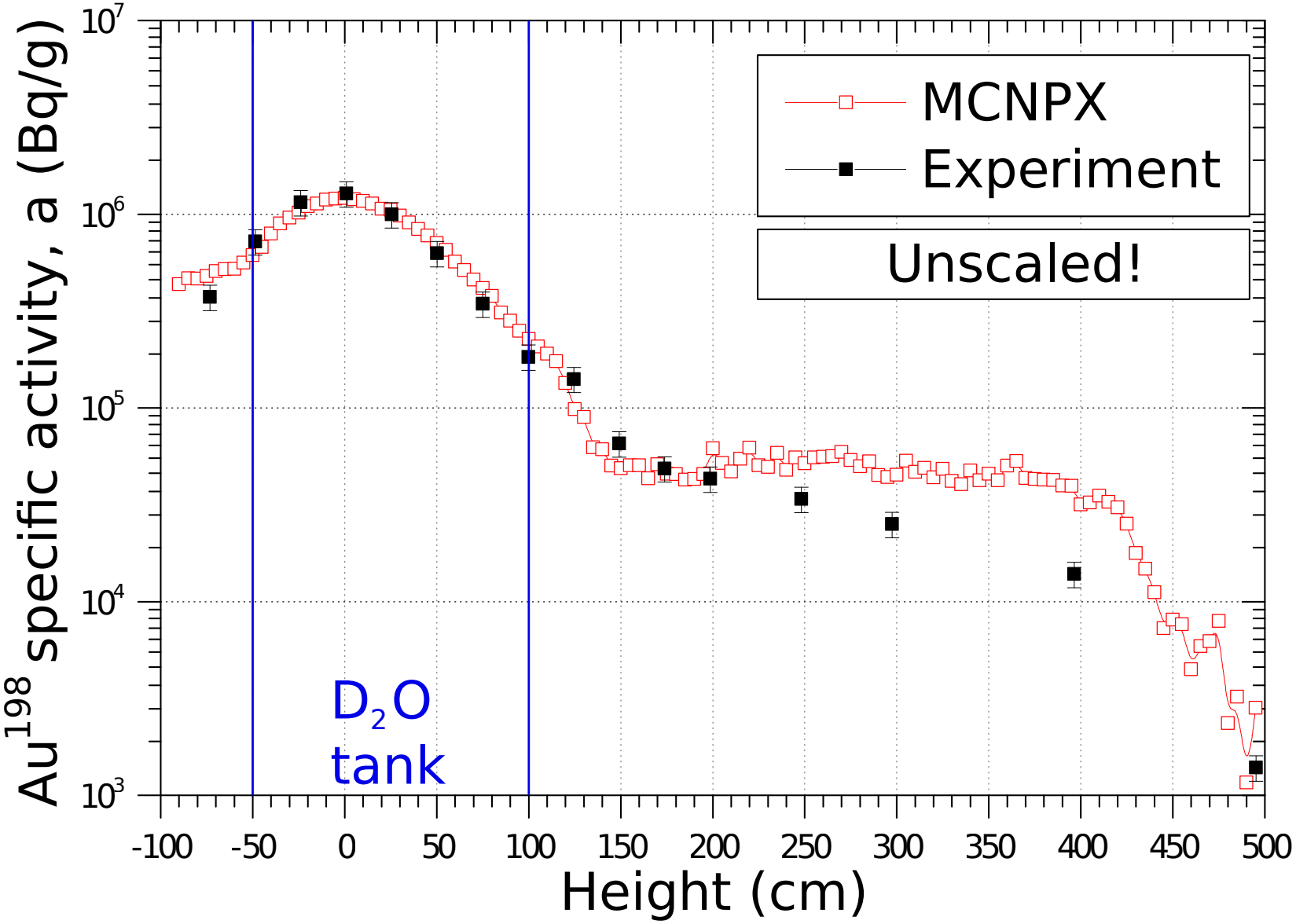
Gold foils, laser cut.



Nylon rope assembly.

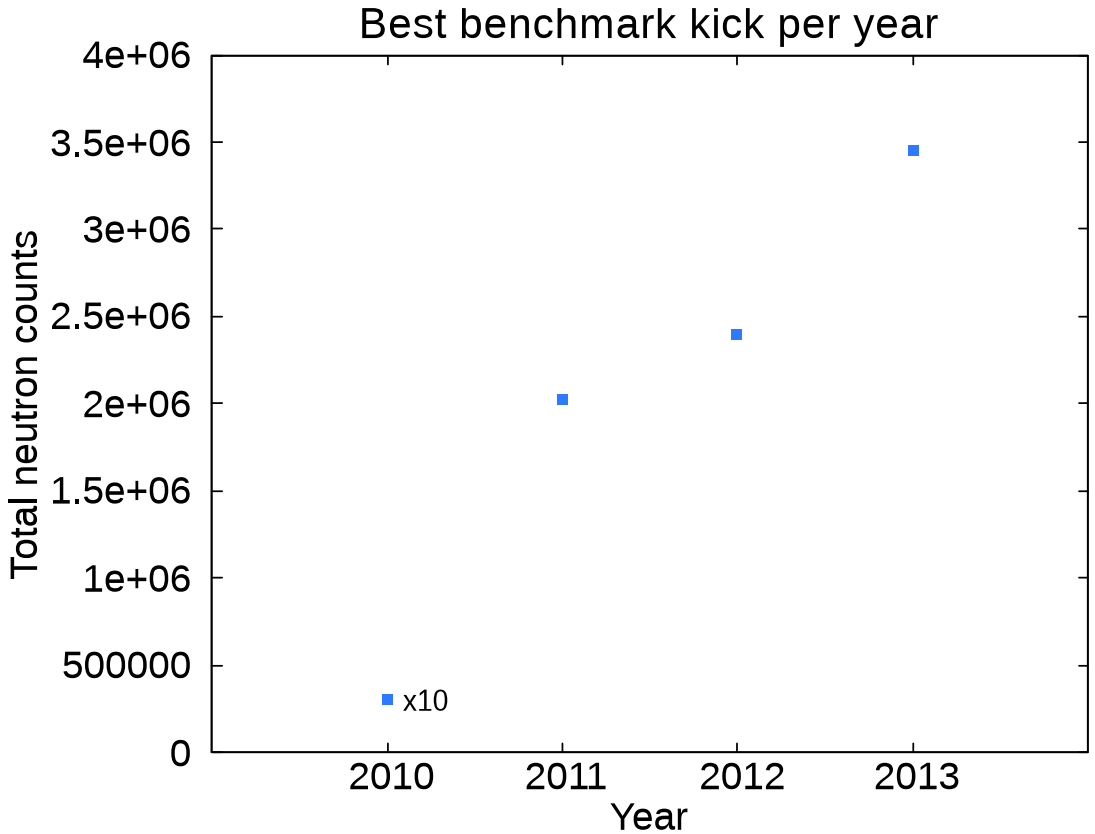


Comparison to MCNPX calculations



Continuous improvements

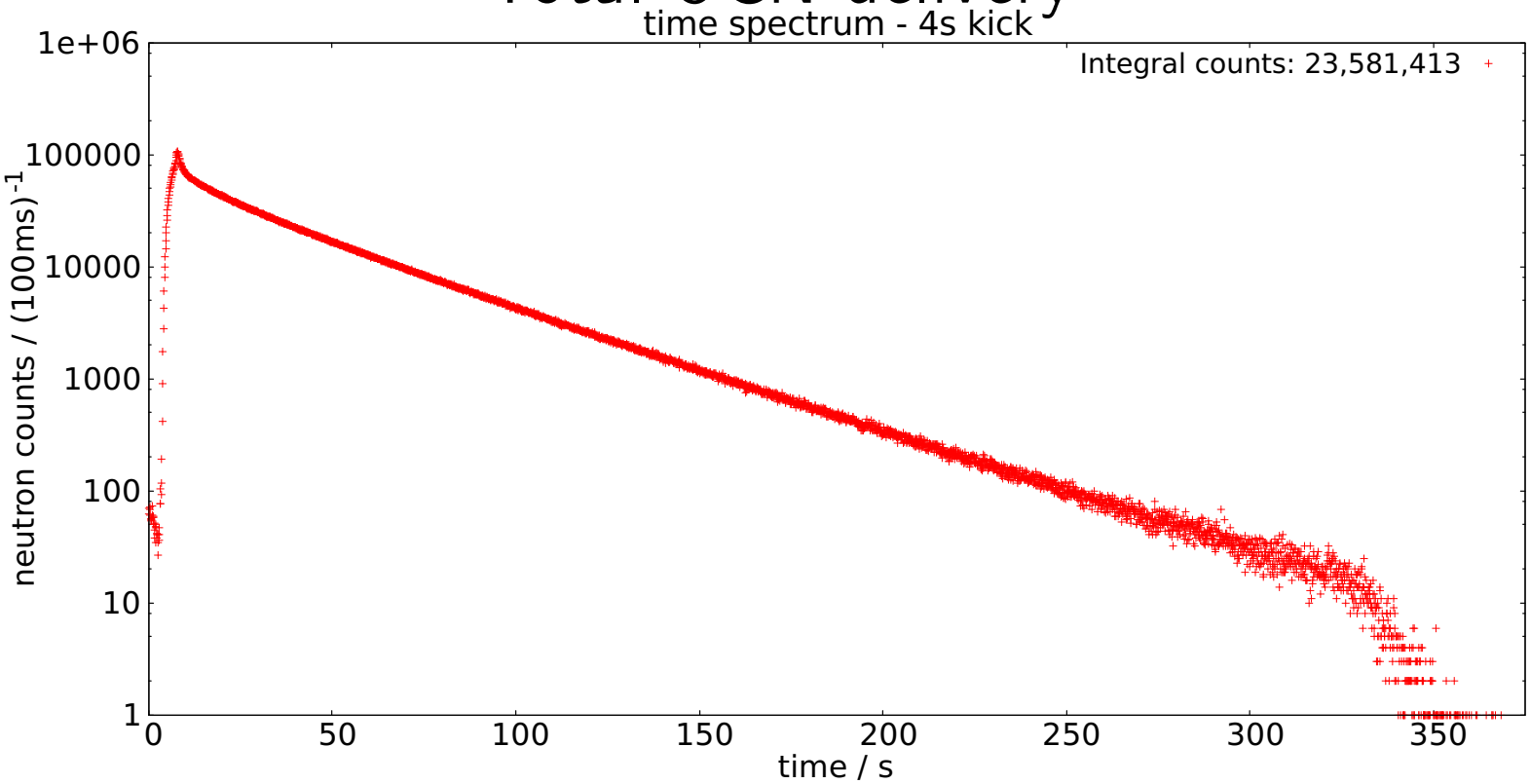
- New He valves since 2012: Better control of the coolant flow.
- More D_2 in the system since 2013: Increased cold neutron flux.
- Optimised proton beam tune:
  - Smaller proton beam size: Less losses at collimators.
  - Beam center above target axis: Increased neutron flux in D_2.



Ongoing UCN program

- Optimisation of D_2 freezing process.
- Validation of UCN Monte Carlo simulations.
- Characterisation of various parts of the source:
  - UCN guides
  - Storage volume.
  - Window transmission
- Measurement of the cold neutron flux in the solid D_2.
- Optimisation of shutter timing.
- Feed nEDM experiment at beamport south.
- Test experiments, e.g. UCN detector tests, at beamport west-2.

Total UCN delivery



Total number of UCN, 4 s proton beam kick: $\sim 23 \times 10^6$ UCN.
Repetition frequency: $\sim 180\,\mathrm{d}^{-1}$.

$$\text{Total:} \quad \sim 4 \times 10^9\,\mathrm{UCN/d}$$

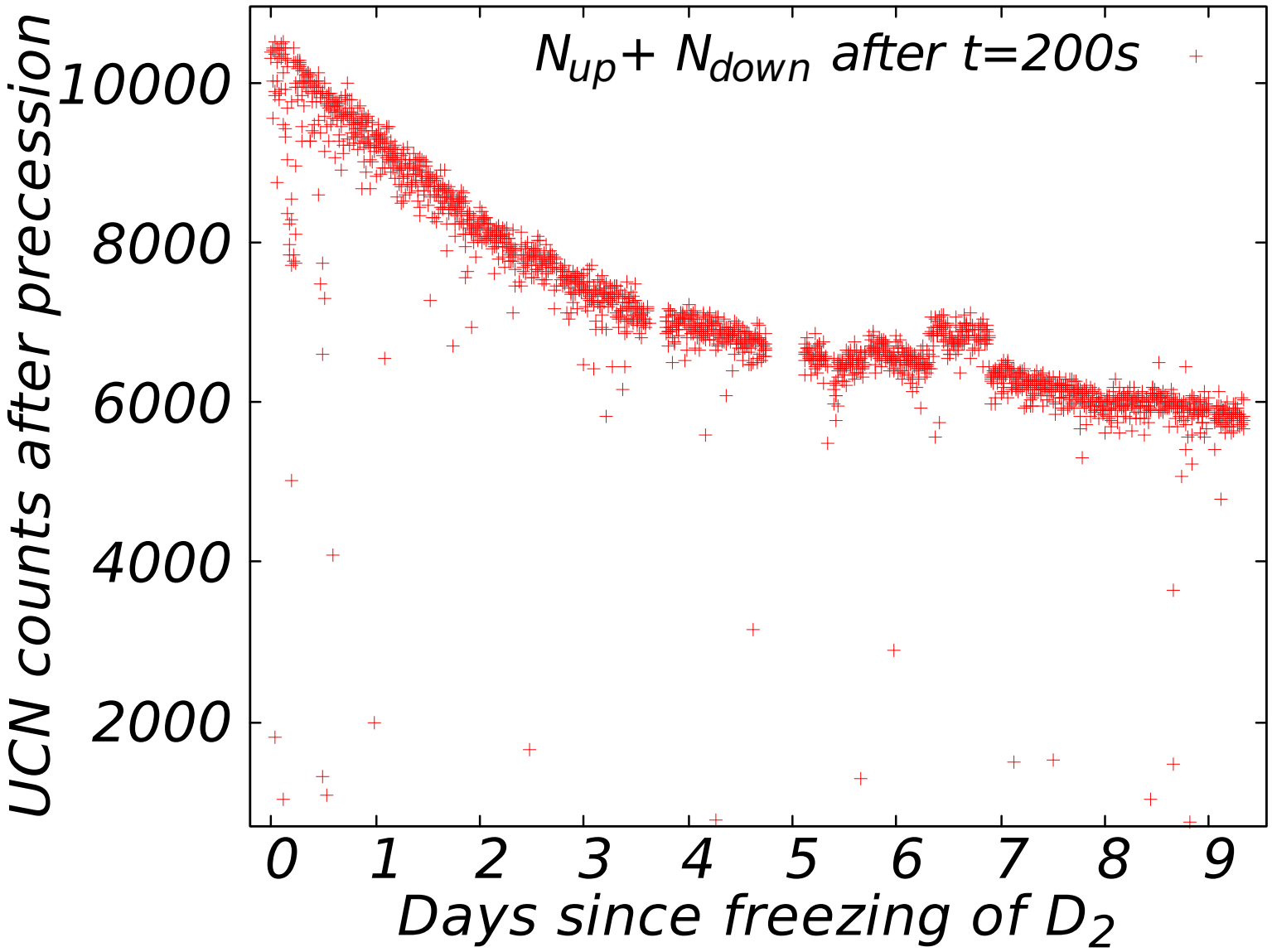
Conclusions

- The UCN source at the Paul Scherrer Institut is in regular operation.
- Presently a UCN density of 30 UCN/cm^3 can be measured at the beamport.
- Characterisation and improvement program is ongoing.
- Improvements of up to an order of magnitude may still be feasible.
- Experiments at the beamports are regularly supplied with UCN.

Thank you for your Attention

Backup

UCN intensity vs time

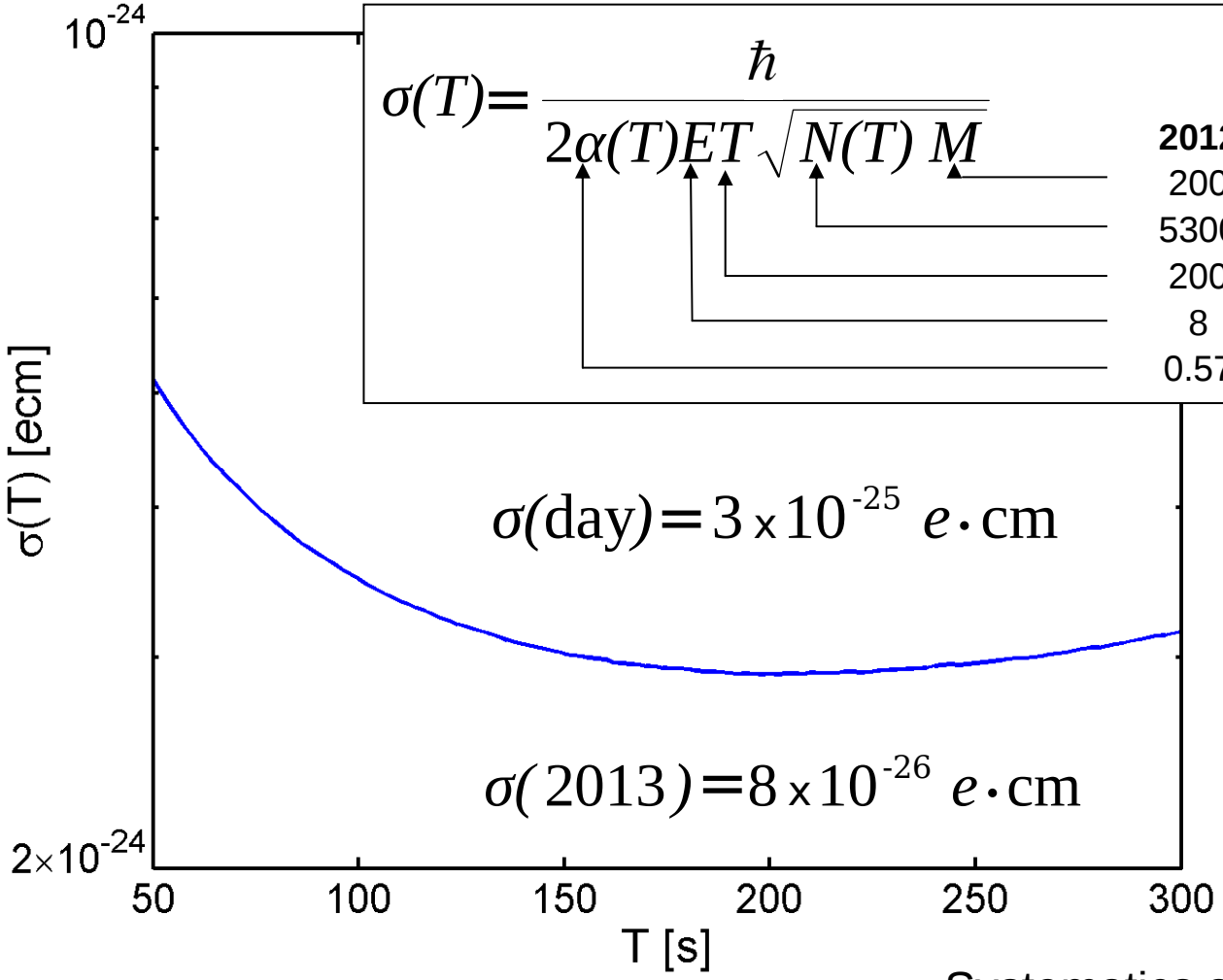


nEDM performance at beamport south

Expected daily sensitivity as function of free precession time T:

$$\sigma(T) = \frac{\hbar}{2\alpha(T) E T \sqrt{N(T)\, M}}$$

	2012	2013	Avg
M	200	210	cycles
$N(T)$	5300	7000	$N_u + N_d$
T	200	180	s
E	8	10.2	kV/cm
$\alpha(T)$	0.57	0.58	



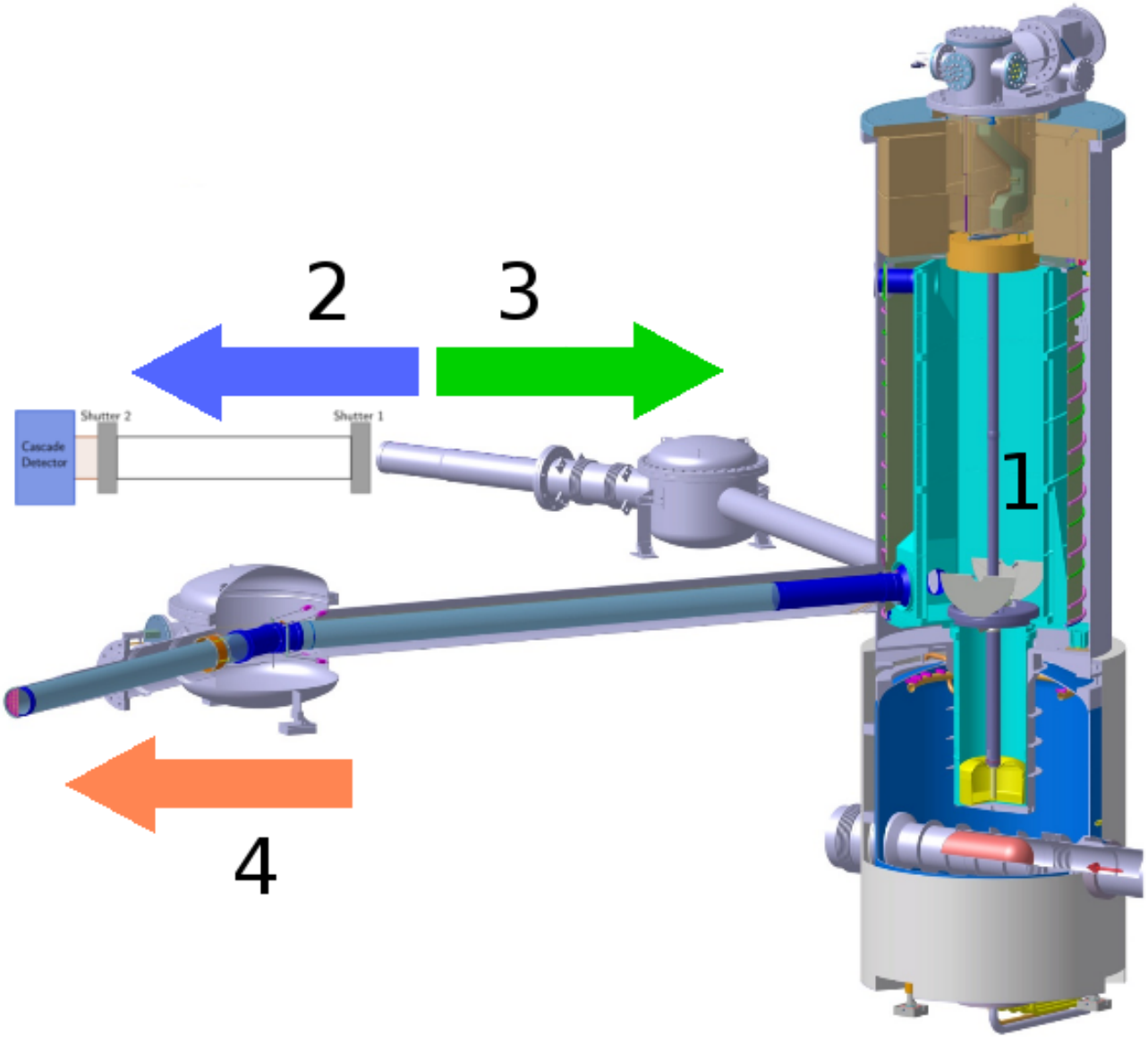
Approximately same sensitivity as Baker et al. [1] at ILL.

Goal 2013: 90 days

Systematics see poster P.N. Prashanth

[1] Baker et al. PRL(2006) 131801

"Ping-Pong": Characterisation of the guide system



- Produce UCN
- Store at one beamport
- Empty source volume
- Release UCN towards source
- Detect at other beamport

"Ping-Pong" vs MC