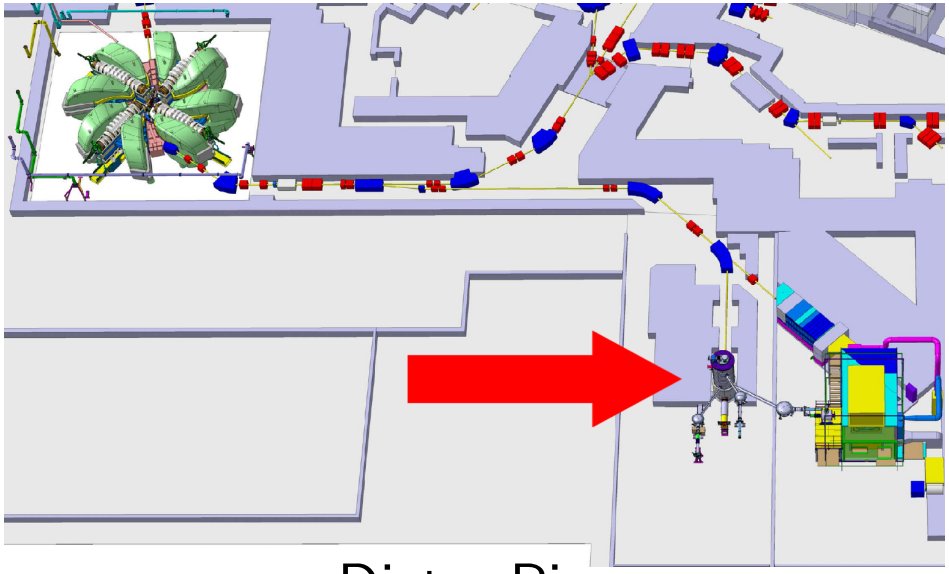
Studies of neutron transport and extraction at the PSI source for Ultracold Neutrons

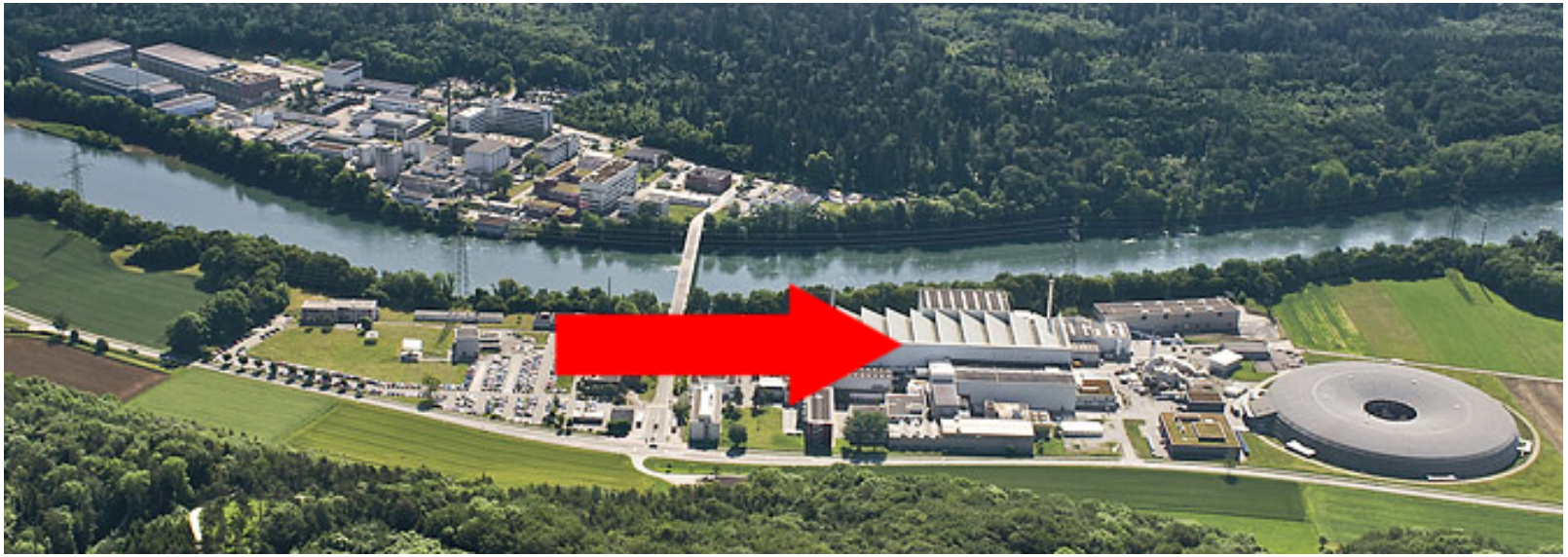


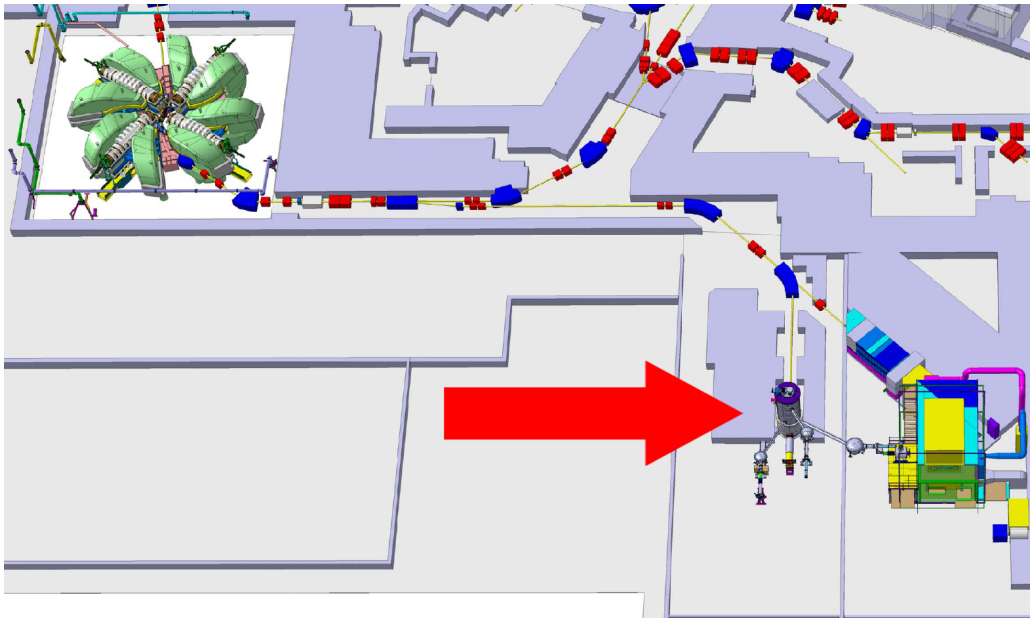
Dieter Ries
on behalf of the PSI UCN project team

ETHZ / UZH PhD Seminar 2015

August 26, 2015

Location





- Paul Scherrer Institut
- 590 MeV proton accelerator
- 2.2 mA beam current
- up to ∼2.5 % duty cycle

Ultracold Neutrons (UCN)

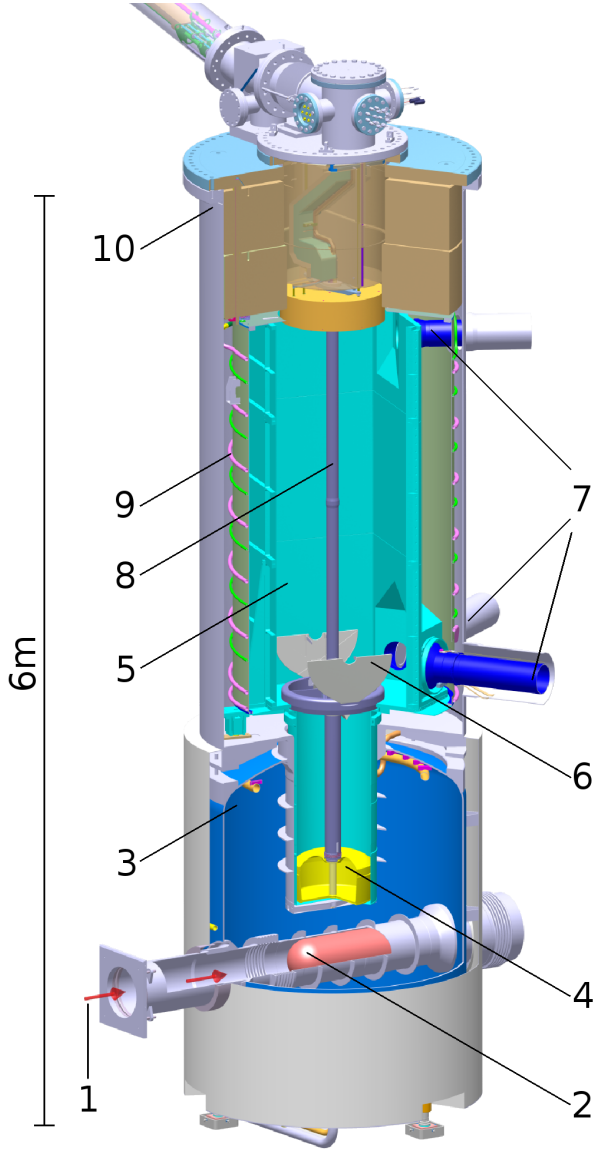
Ultracold:

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

Why?

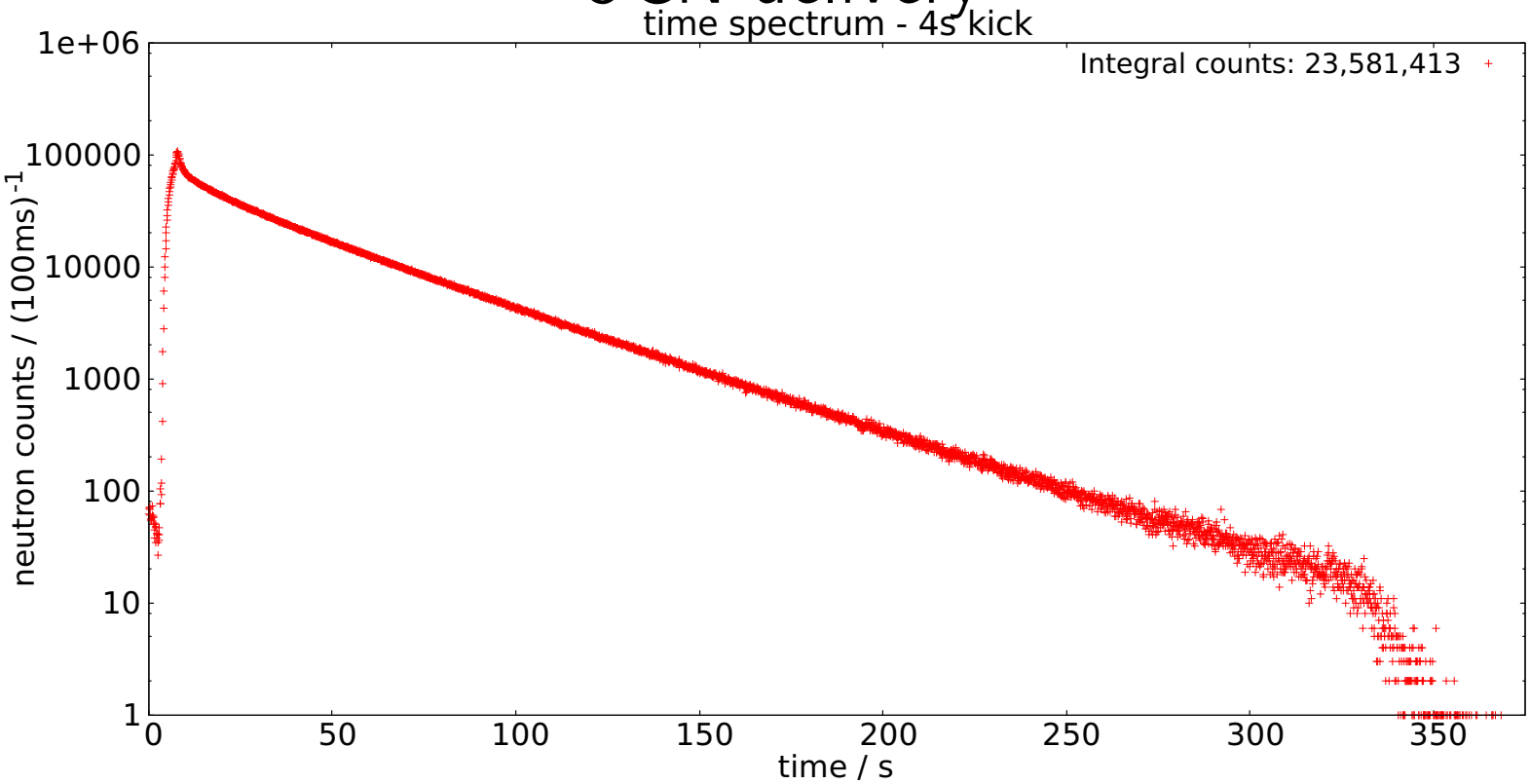
- Materials with effective wall potentials up to 335 neV (^{58}Ni)
- Storage of UCN by total reflection under any angle of incidence
- Storage times comparable to the free neutron lifetime
- Research on free neutrons with long observation time

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
5. $\sim$2 m^3 UCN storage vessel, Diamond like Carbon (DLC) coating
6. Storage vessel shutter
7. UCN guides towards experiments
   - $\sim$8 m long
   - coated with NiMo
8. He and D_2 supply lines
9. Thermal shield
10. Vacuum tank

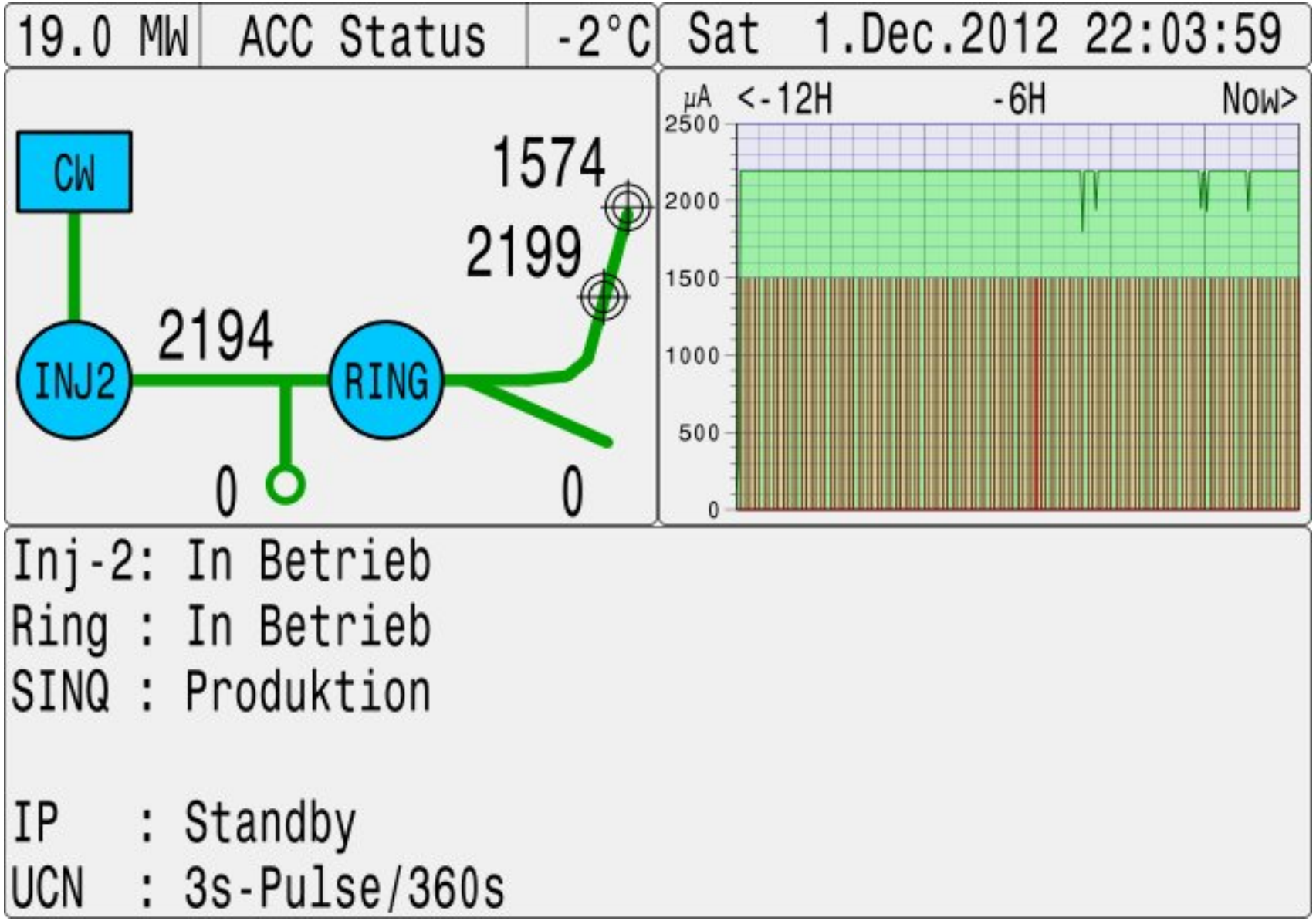
UCN delivery



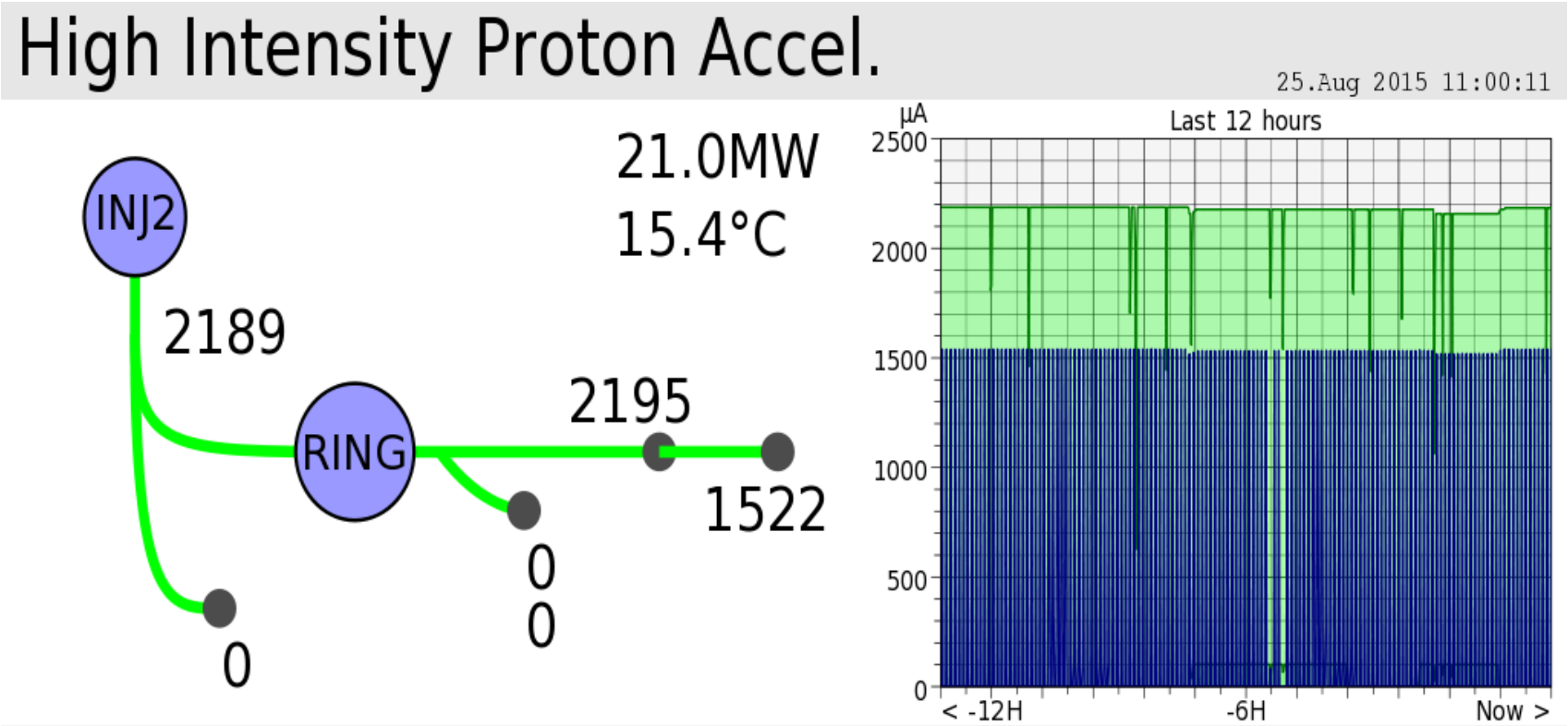
Total number of UCN, 4 s proton beam kick: $\sim 23 \times 10^6$ UCN.
Repetition frequency: $\sim 280\,\mathrm{d}^{-1}$.

$$\text{Total:} \quad \sim 6.4 \times 10^9\,\mathrm{UCN/d}$$

In regular operation since 2012 ...



... and running as we speak

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Inj-2: Production
Ring : Production
SINQ : Production

IP   : idle
UCN  : 4.1s-pulse/300s
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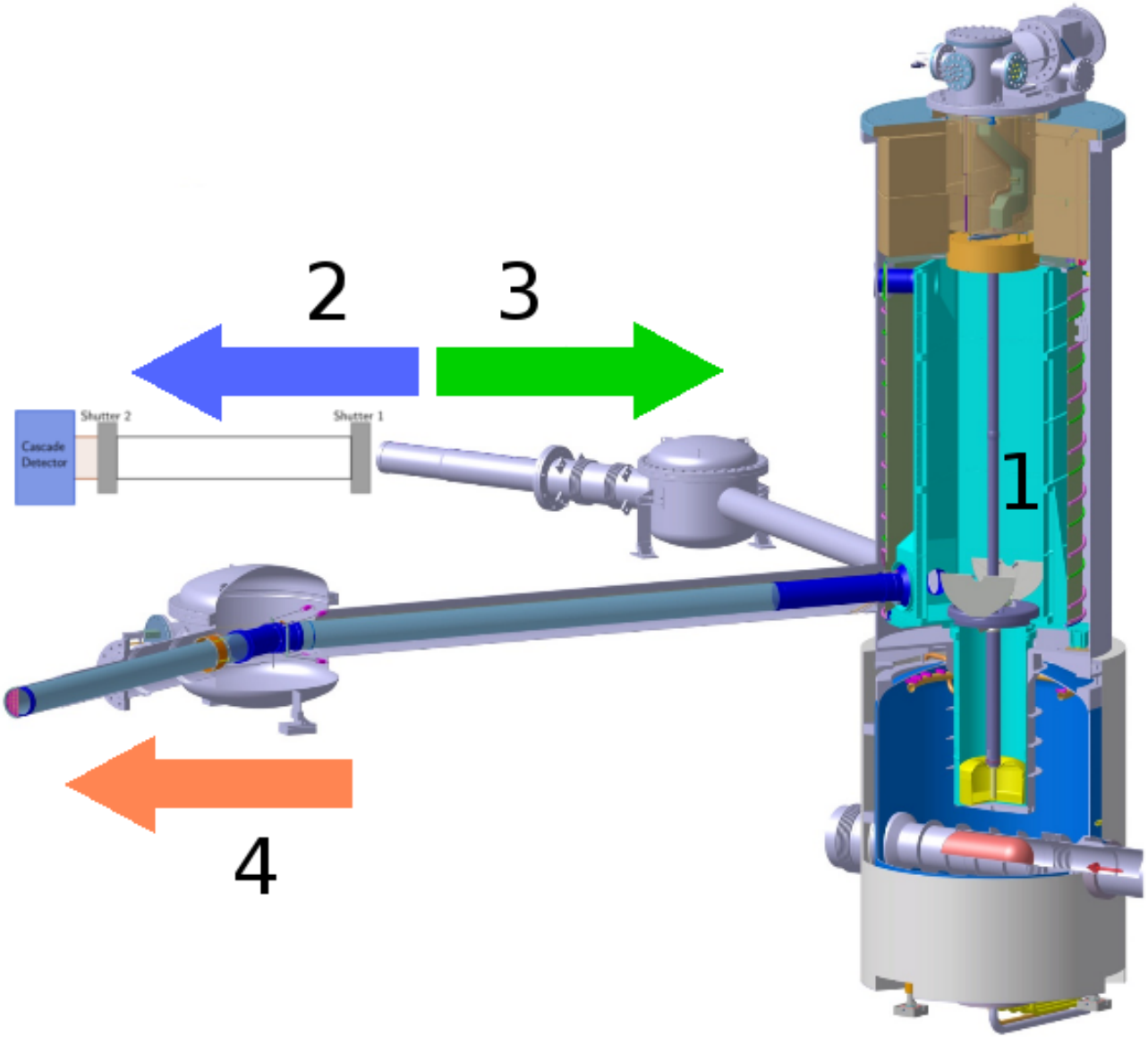
UCN Extraction and Transport

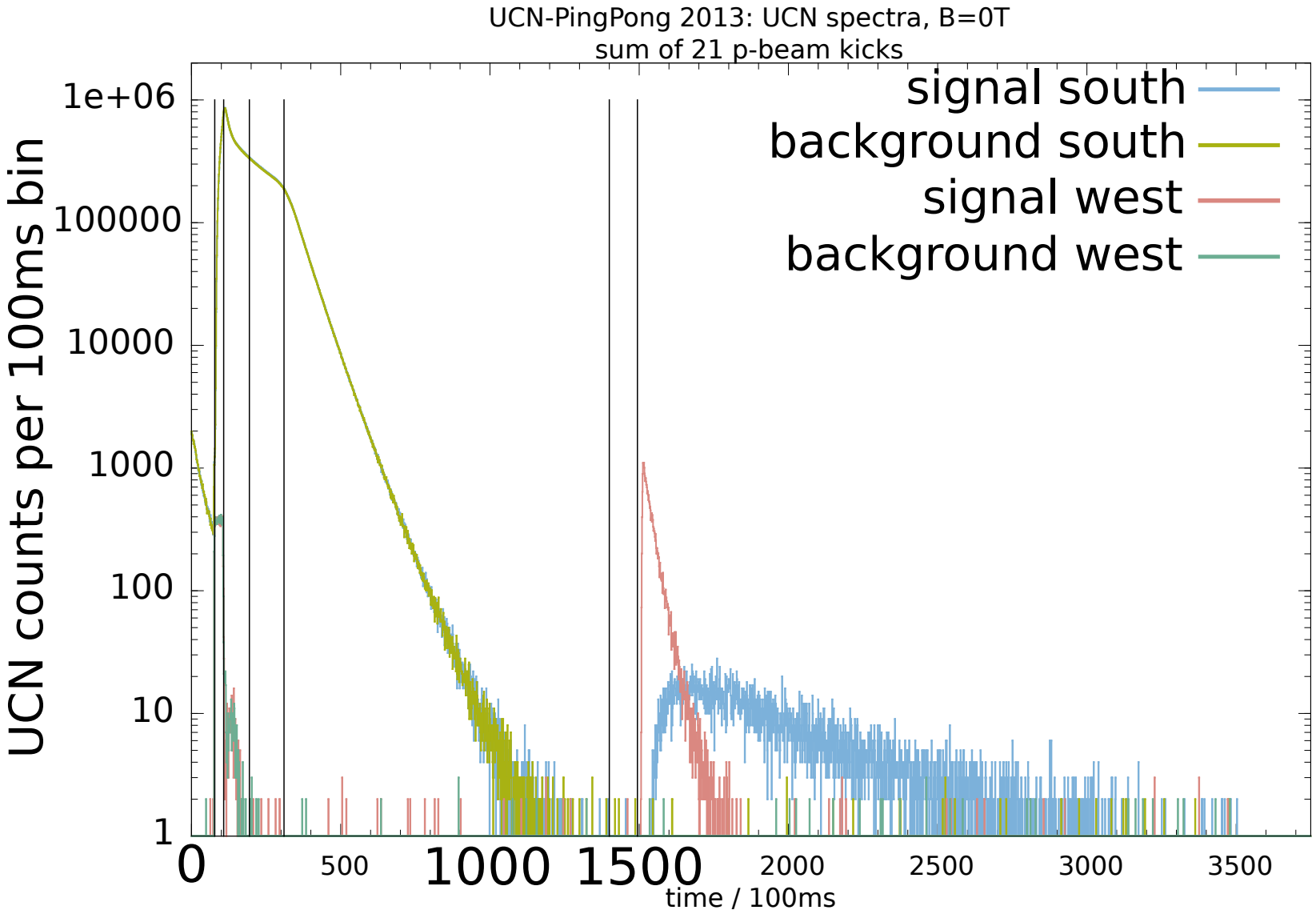
- Source surrounded by many cubic meters of shielding (iron, concrete)
- Experiments situated outside of the shield stack
- UCN extraction efficiency from production to experiment important
- Guides tested prior to assembly of the source
- in situ measurement more meaningful:
  - includes safety windows
  - includes assembly gaps
  - includes all UCN guide shutters
- how to normalize such a measurement?

"Ping-Pong": Characterisation of the guide system



1. Produce UCN
2. Store at one beamport
3. Release UCN towards source
4. Detect at other beamport

UCN Transport - Time Spectrum



UCN Transport - Results

- UCN transmission compatible with analytical calculations
- Time spectra qualitatively match MC calculations
- Refine MC model:
  - Beamline shutter movement
  - Initial conditions in the external bottle
  - Transmission through vacuum safety foils

No surprises, no black holes eating UCNs inside the guide system!

UCN Source Comparison - Introduction

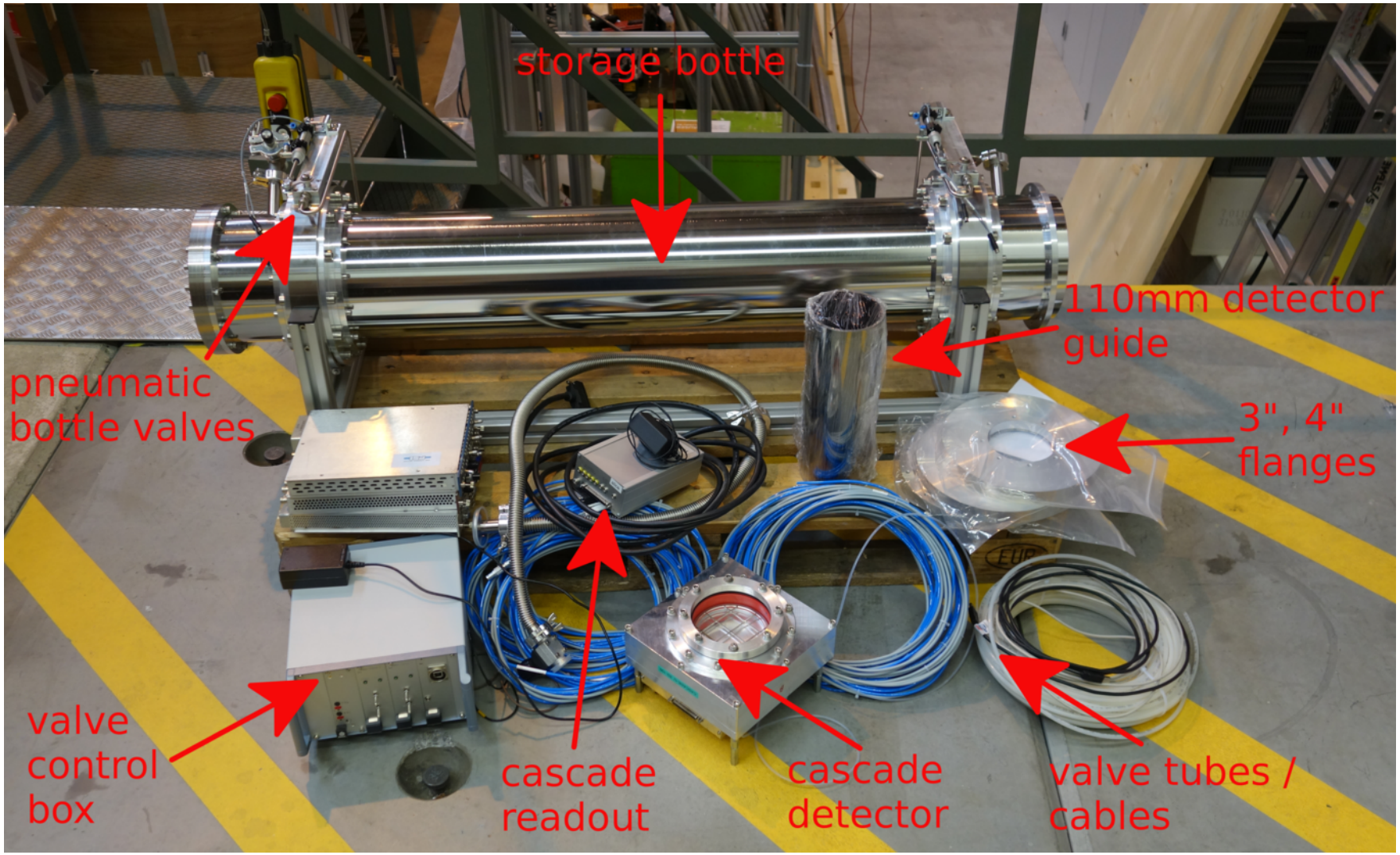
UCN sources in operation:

- PSI (spallation + sD_2)
- PF2 @ ILL (reactor + turbine)
- SUN2 @ ILL (reactor + lHe)
- LANL (spallation + sD_2)
- TRIGA Mainz (reactor + sD_2)

Typical UCN experiments:

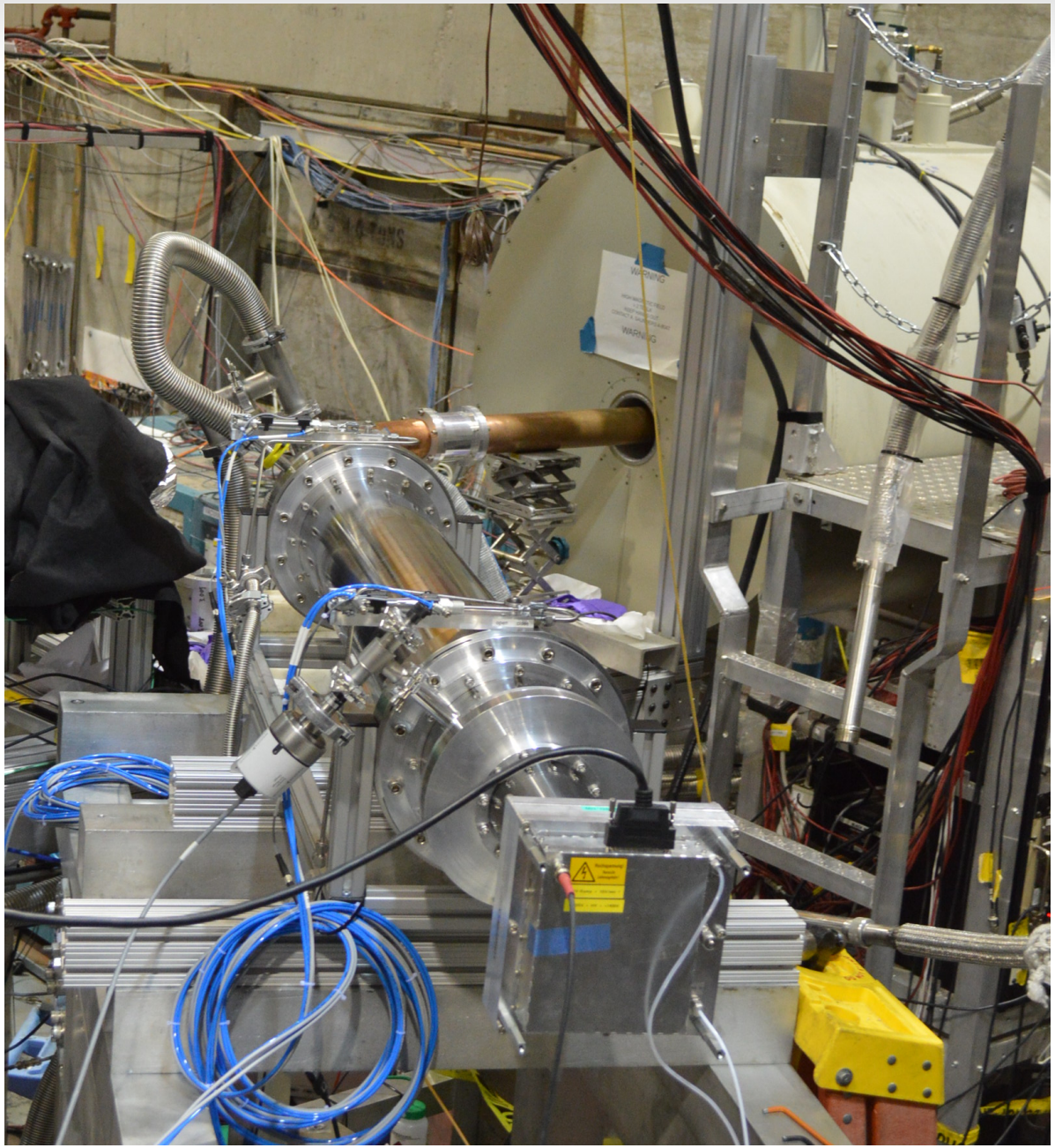
- Long measurement time
- Large and heavy
- Not very portable

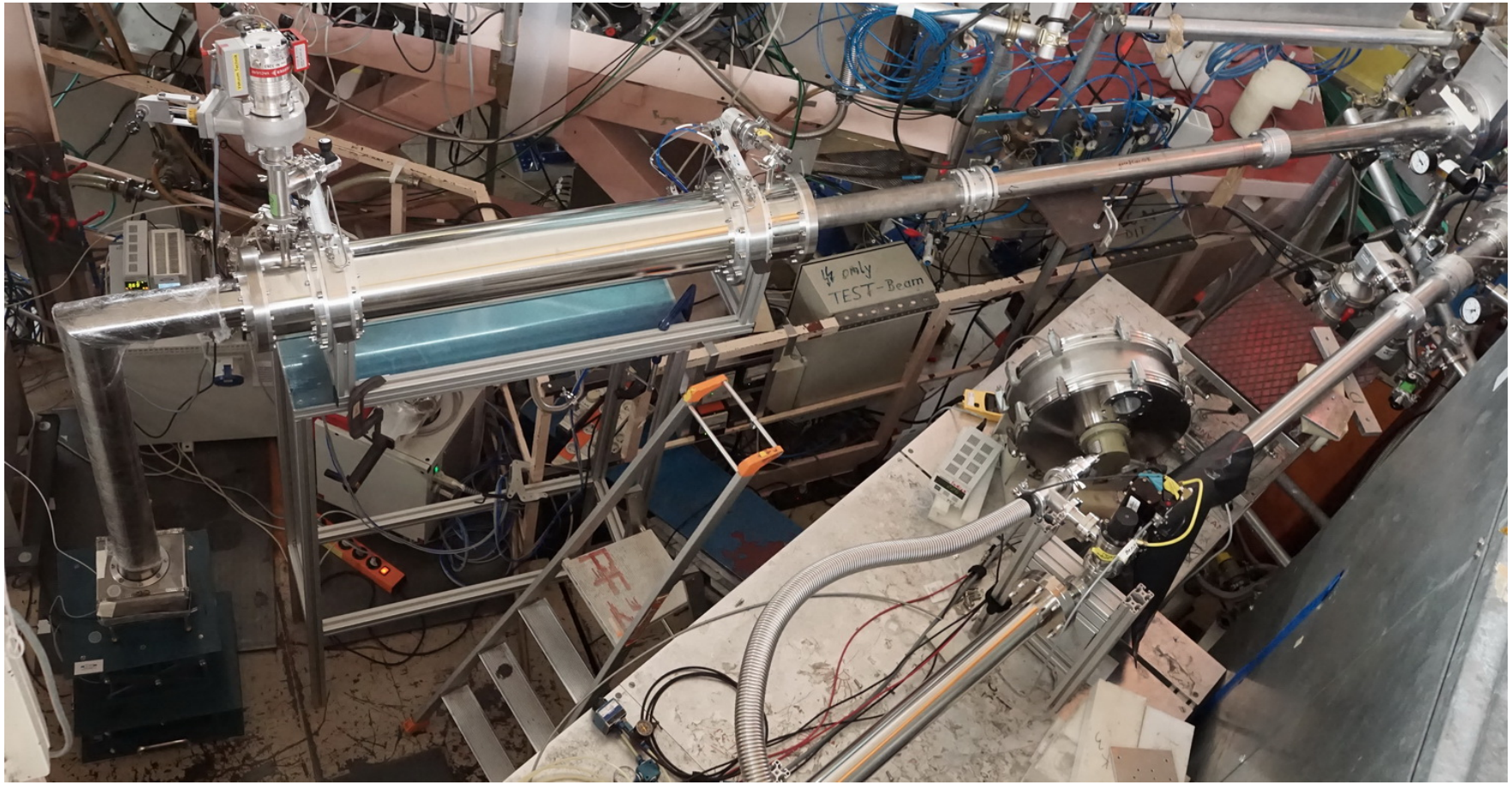
A collaboration to determine UCN densities available at various operating UCN beamports world-wide using standard UCN storage vessels was established.


storage bottle
pneumatic bottle valves
110mm detector guide
3", 4" flanges
valve control box
cascade readout
cascade detector
valve tubes / cables

Schematic View

- Fast butterfly-type shutters (opening/closing time $\ll 1\,\mathrm{s}$)
- Volume between the shutters: 31.4 L
- Measurement sequence:
  1. Filling: Shutter 1 open, shutter 2 closed
  2. Storage: Shutter 1 closed, shutter 2 closed
  3. Counting: Shutter 1 closed, shutter 2 open
- UCN density: counts $\times \frac{1}{31400}$ UCN/cm^3




only
TEST-Beam

Source Comparison - Status

Status

- 3/5 sources measured
- UCN source community happy and welcoming

Outlook:

- Additional measurement at PF2 @ ILL in September
- Measurements at PSI: Oktober
- Measurements at TRIGA Mainz: November
- (Sources under construction ...)
- (Additional UCN bottles?)

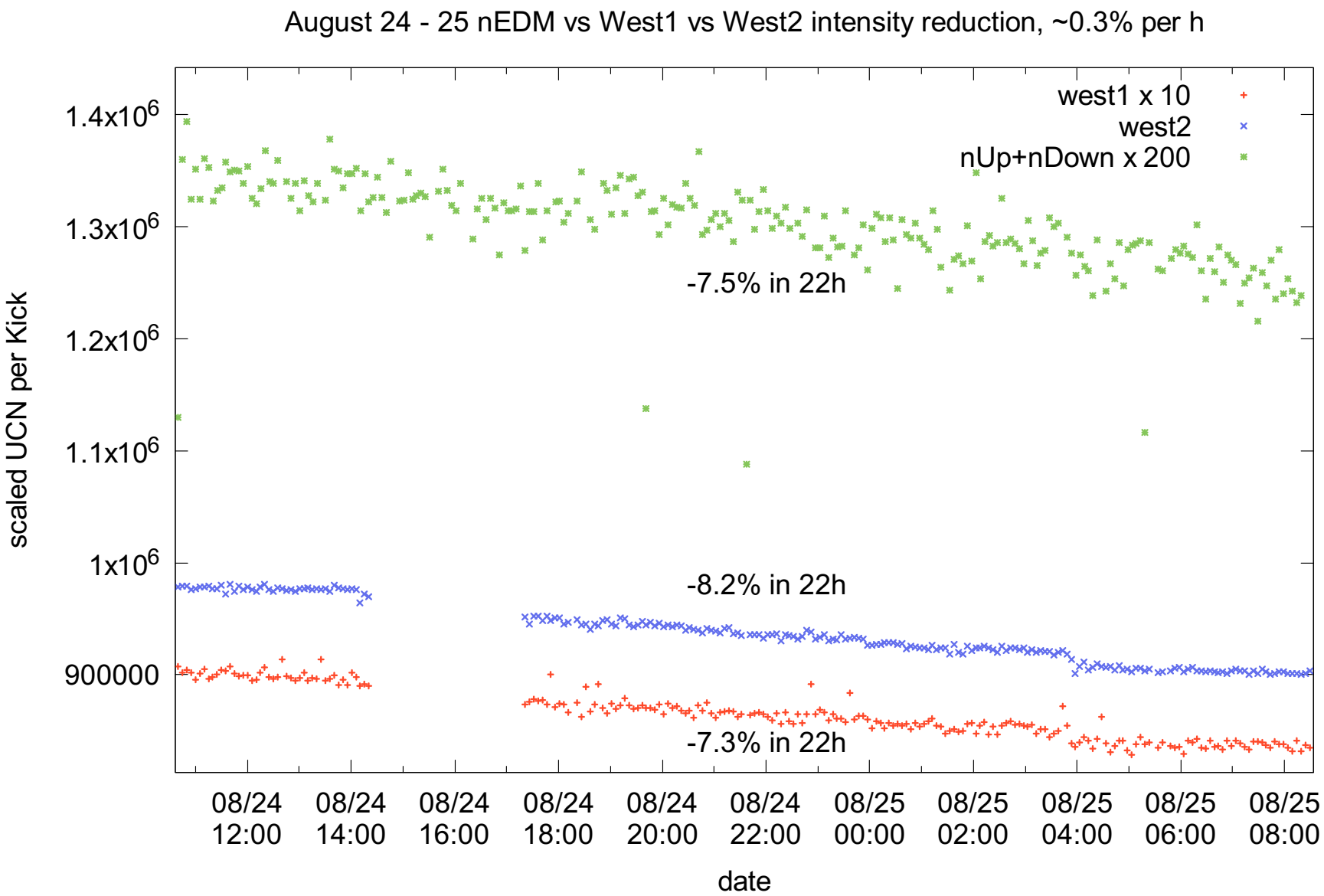
Summary

- The UCN source at the Paul Scherrer Institut is in regular operation.
- Experiments like nEDM are regularly supplied with UCN.
- UCN transport through the source guides has been measaured using UCN stored in a bottle outside the source.
- A world-wide effort to compare UCN sources is ongoing.

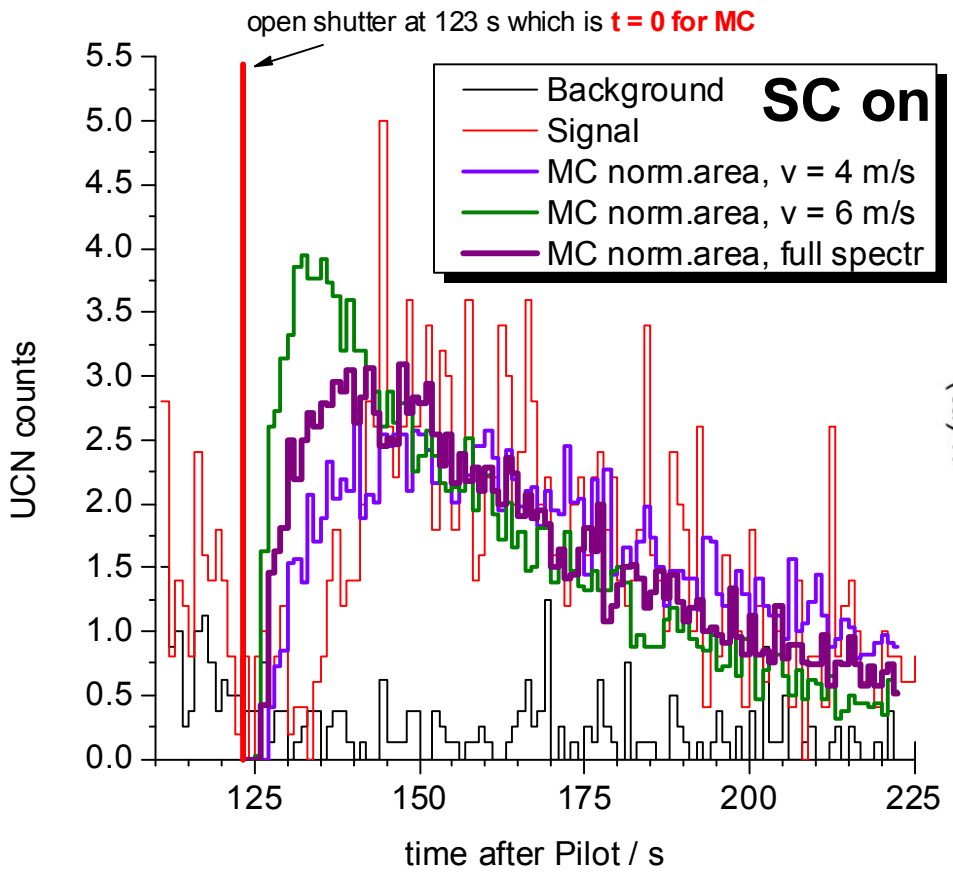
Thank you for your Attention

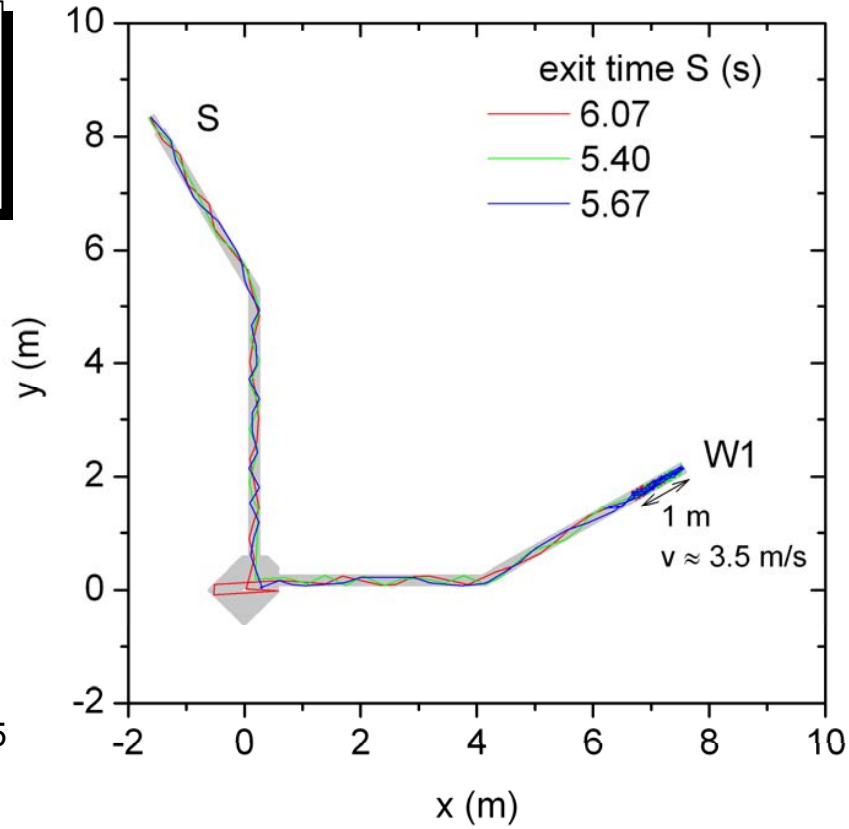
Backup

UCN intensity vs time

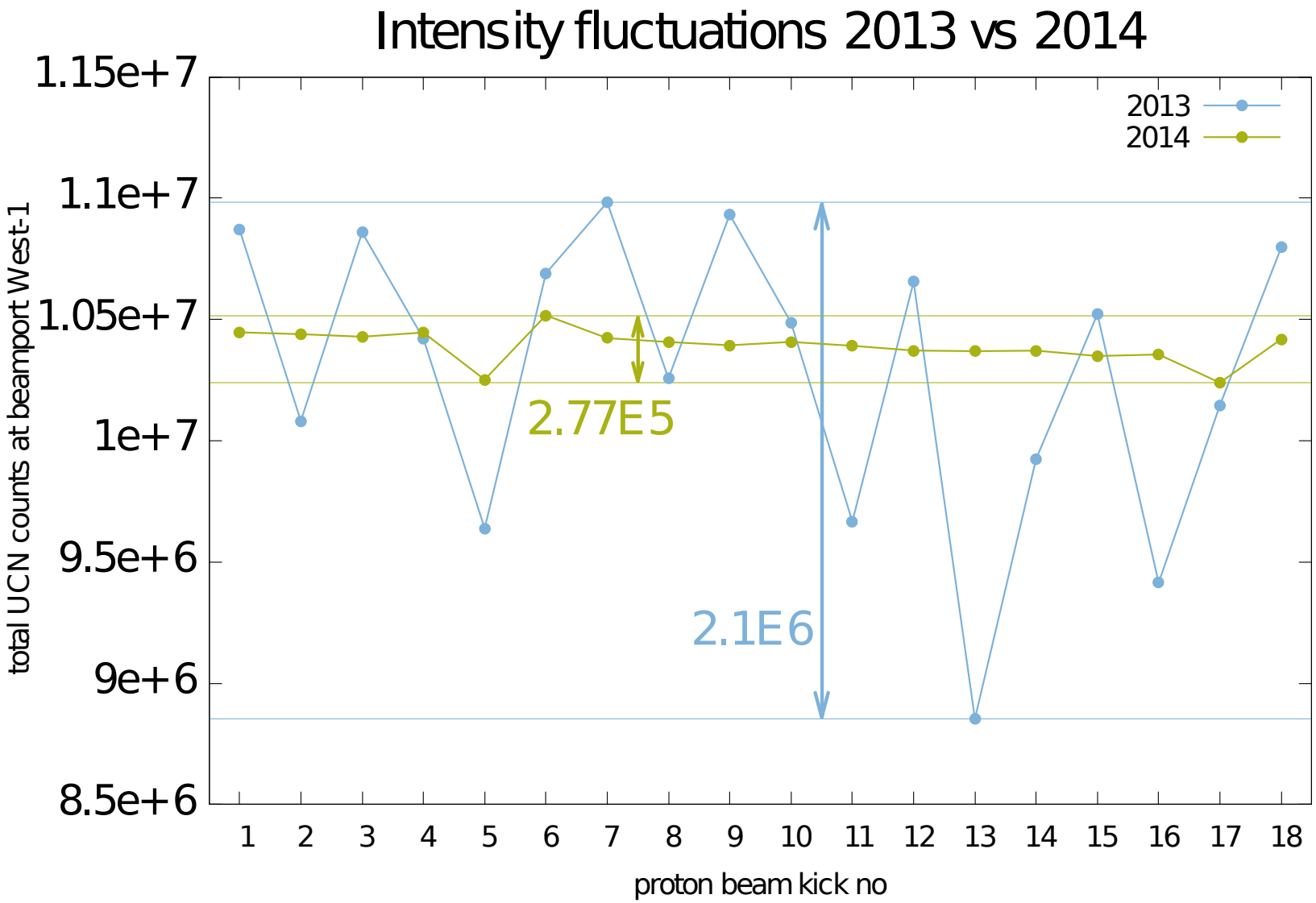


"Ping-Pong" vs MC





Central storage vessel flaps



Optimised timing of storage vessel flaps since 2014