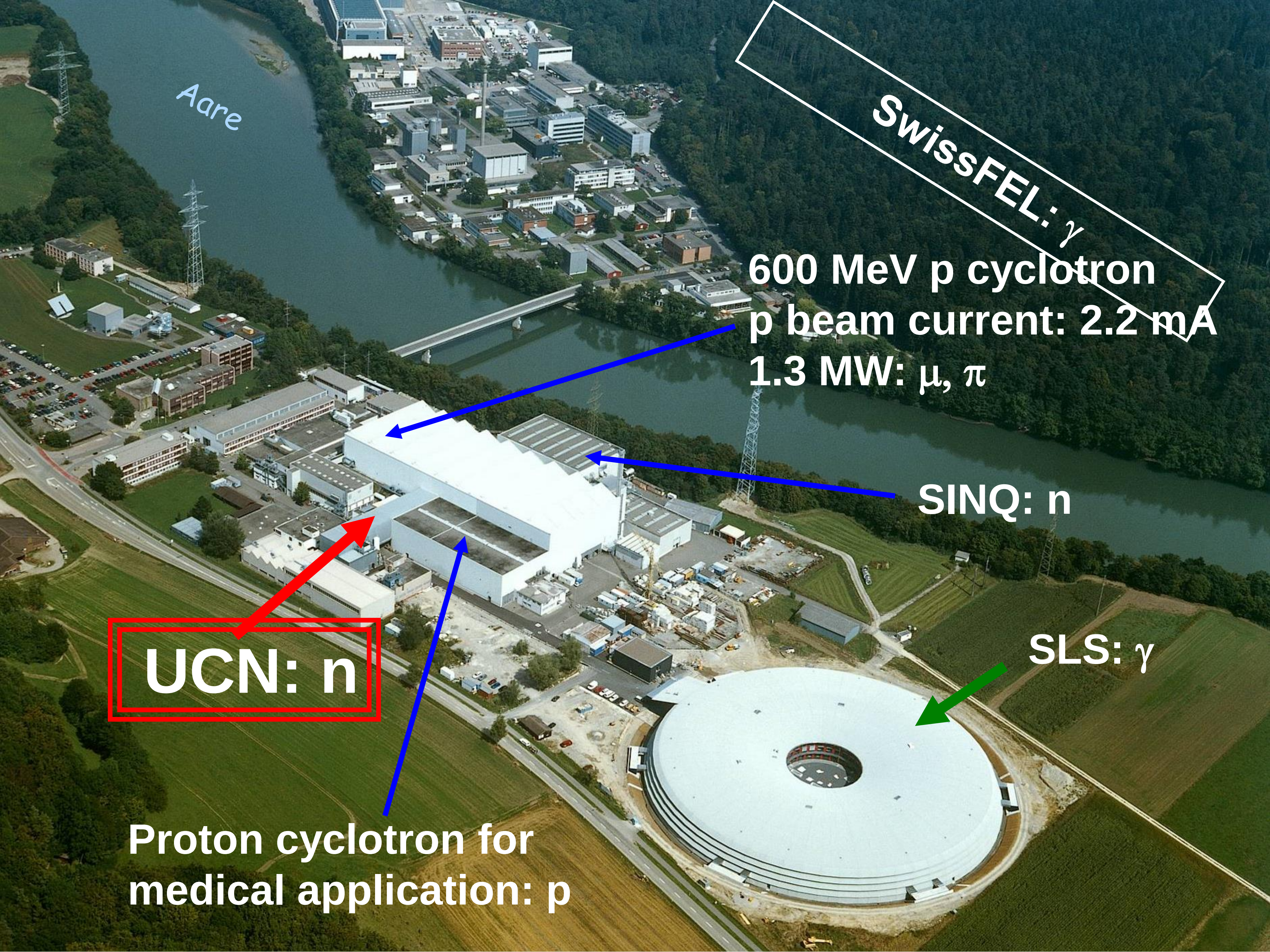
PAUL SCHERRER INSTITUT

Ultra Cold Neutron Source

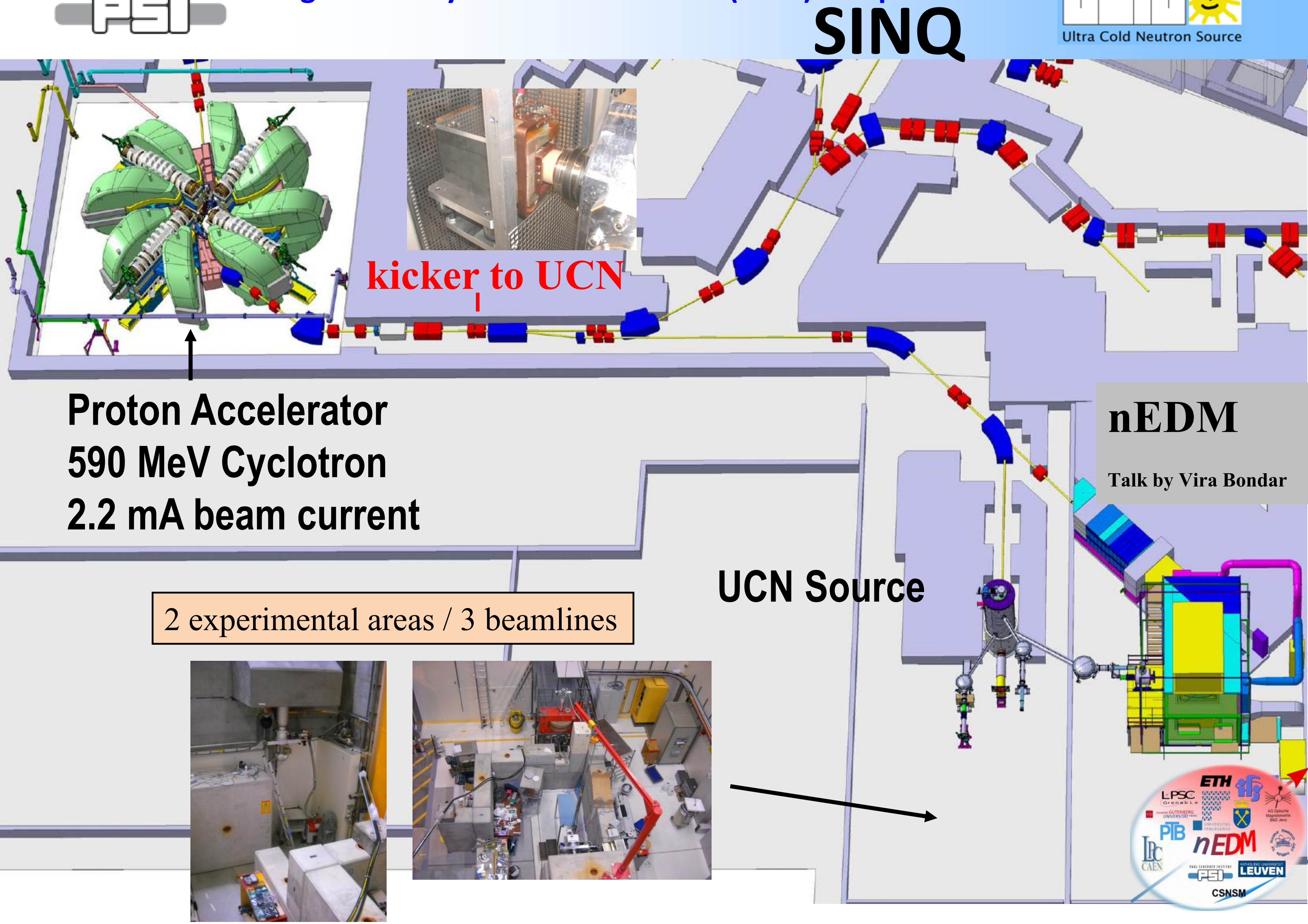
The ultracold neutron facility at the Paul Scherrer Institute

Bernhard Lauss
Paul Scherrer Institute
on behalf of the PSI UCN team

International Workshop:
Probing fundamental symmetries and interactions with UCN
April 11 - 15, 2016
Mainz, Waldthausen Castle

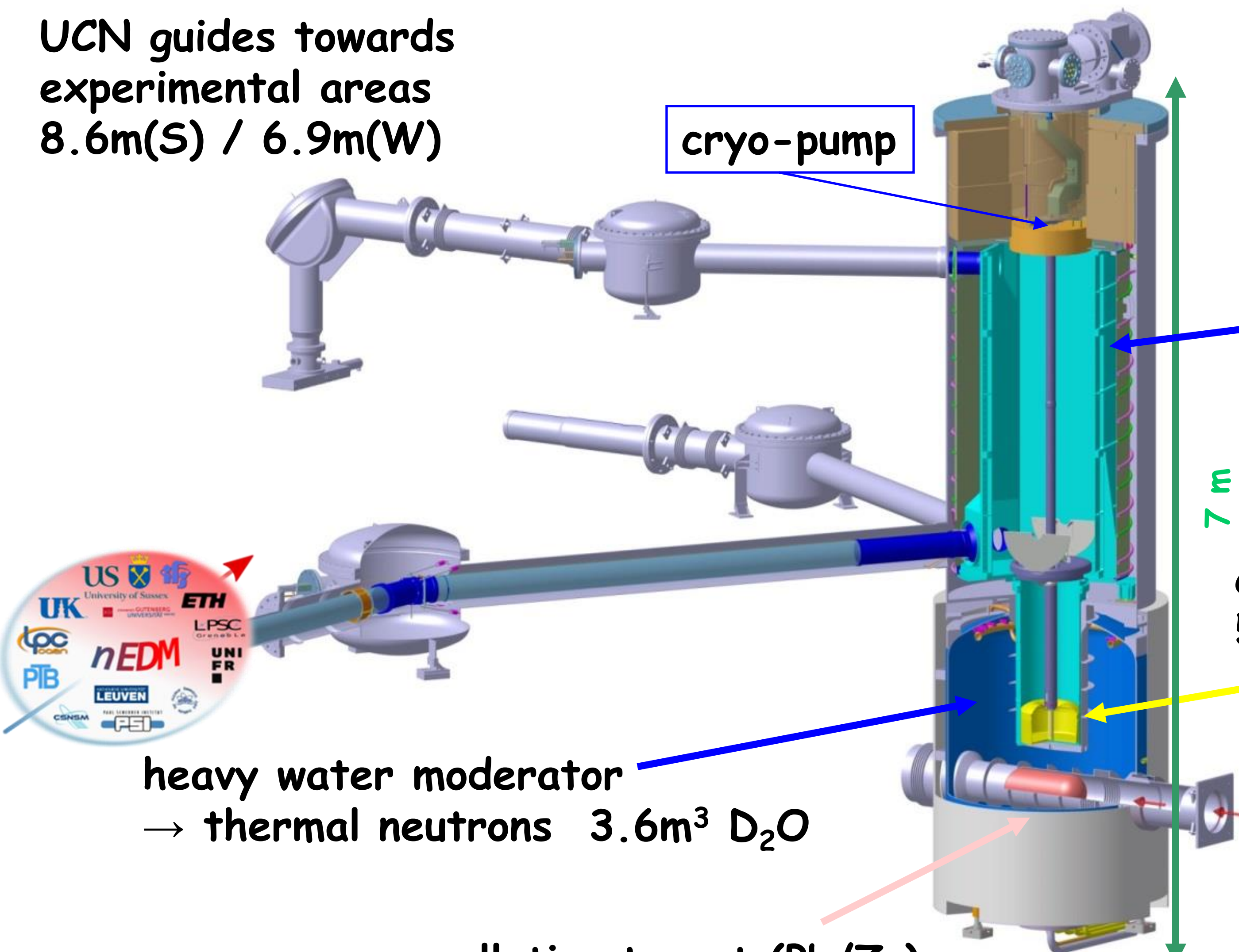

Aare
SwissFEL: γ
600 MeV p cyclotron
p beam current: 2.2 mA
1.3 MW: μ, π
SINQ: n
SLS: γ
UCN: n
Proton cyclotron for
medical application: p

High Intensity Proton Accelerator (HIPA) complex

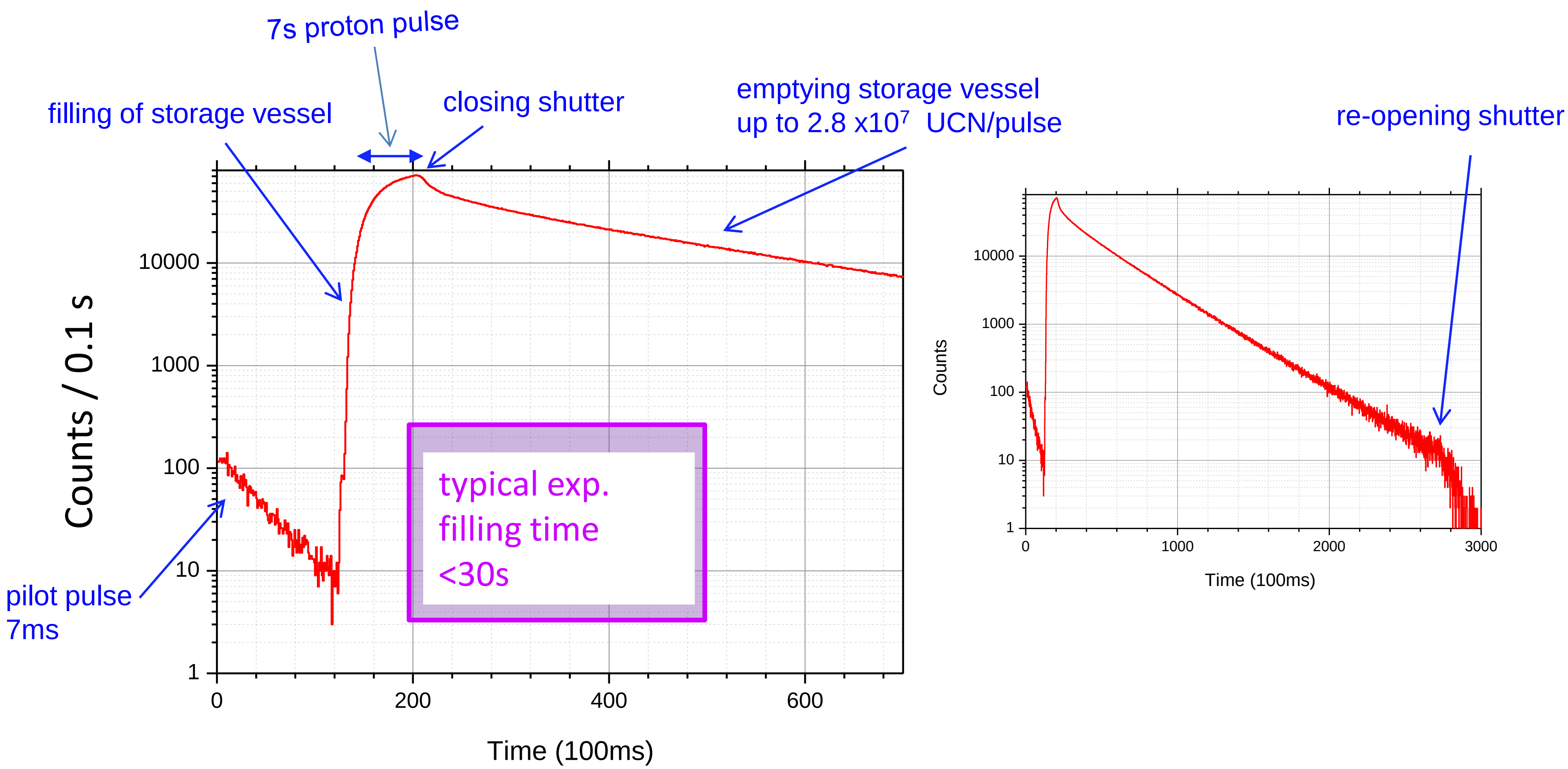


Sketch of the PSI UCN Source:

our strategy: check and understand every step from neutron production to UCN detection



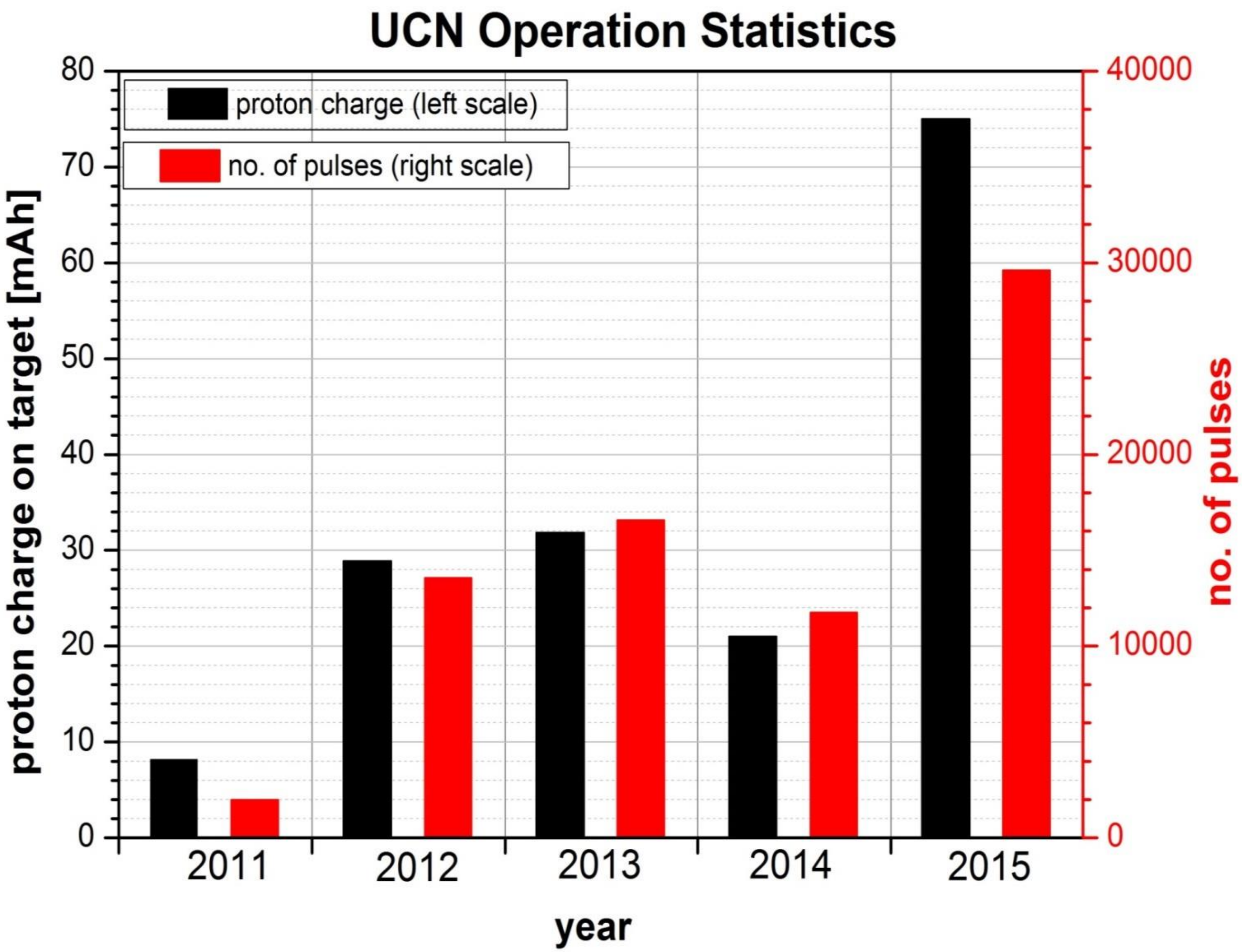
Characterization of UCN output with Cascade detector at beam-port



UCN operations 2011 - 2015

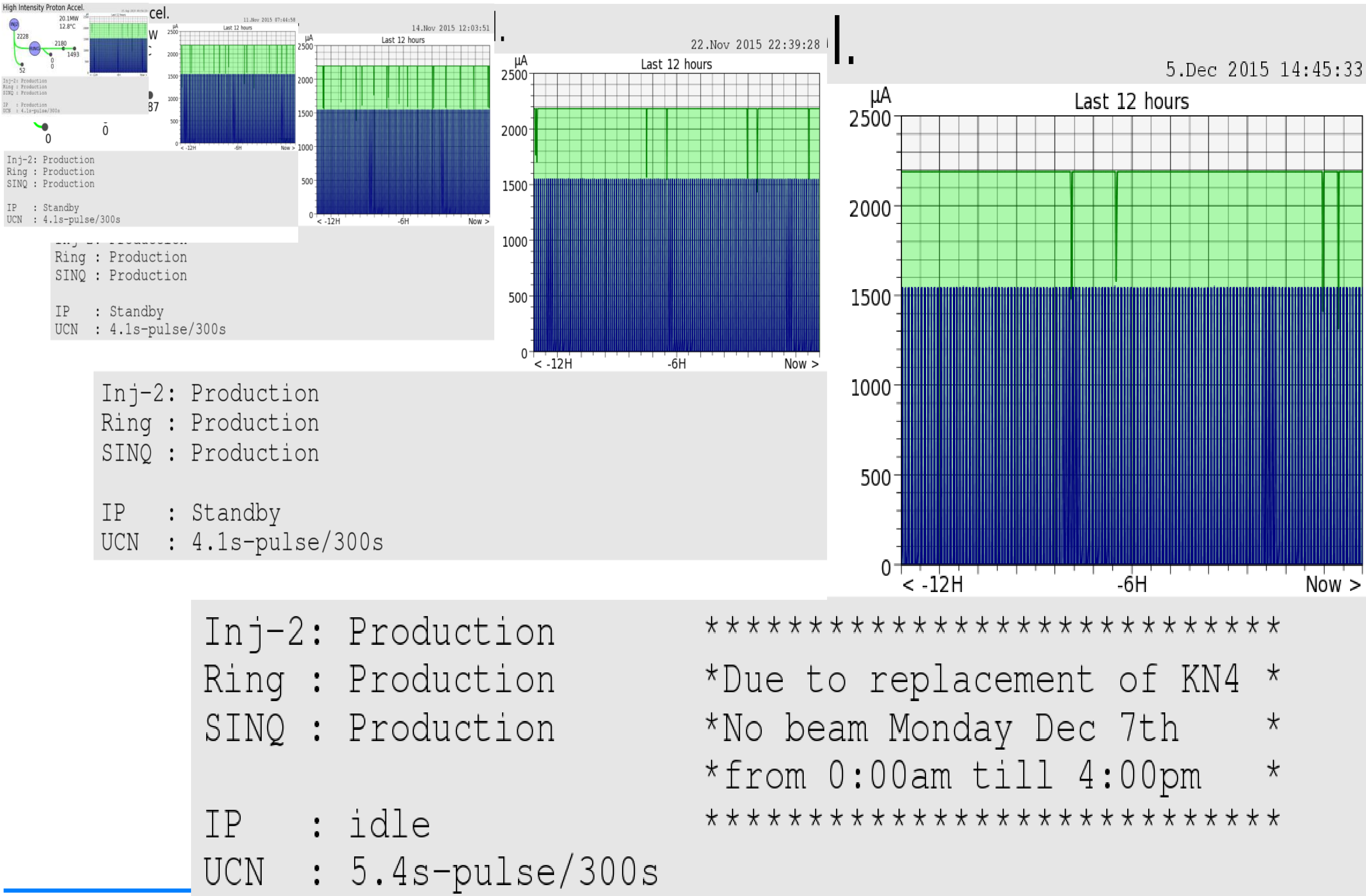
2015: full proton beam operation period (May - Dec.)
~ 200 days
≈ 58'000 pulses

total of ~140 days with UCN available in 2015
→ 124 nEDM data taking days



plot cortesy B.Blau

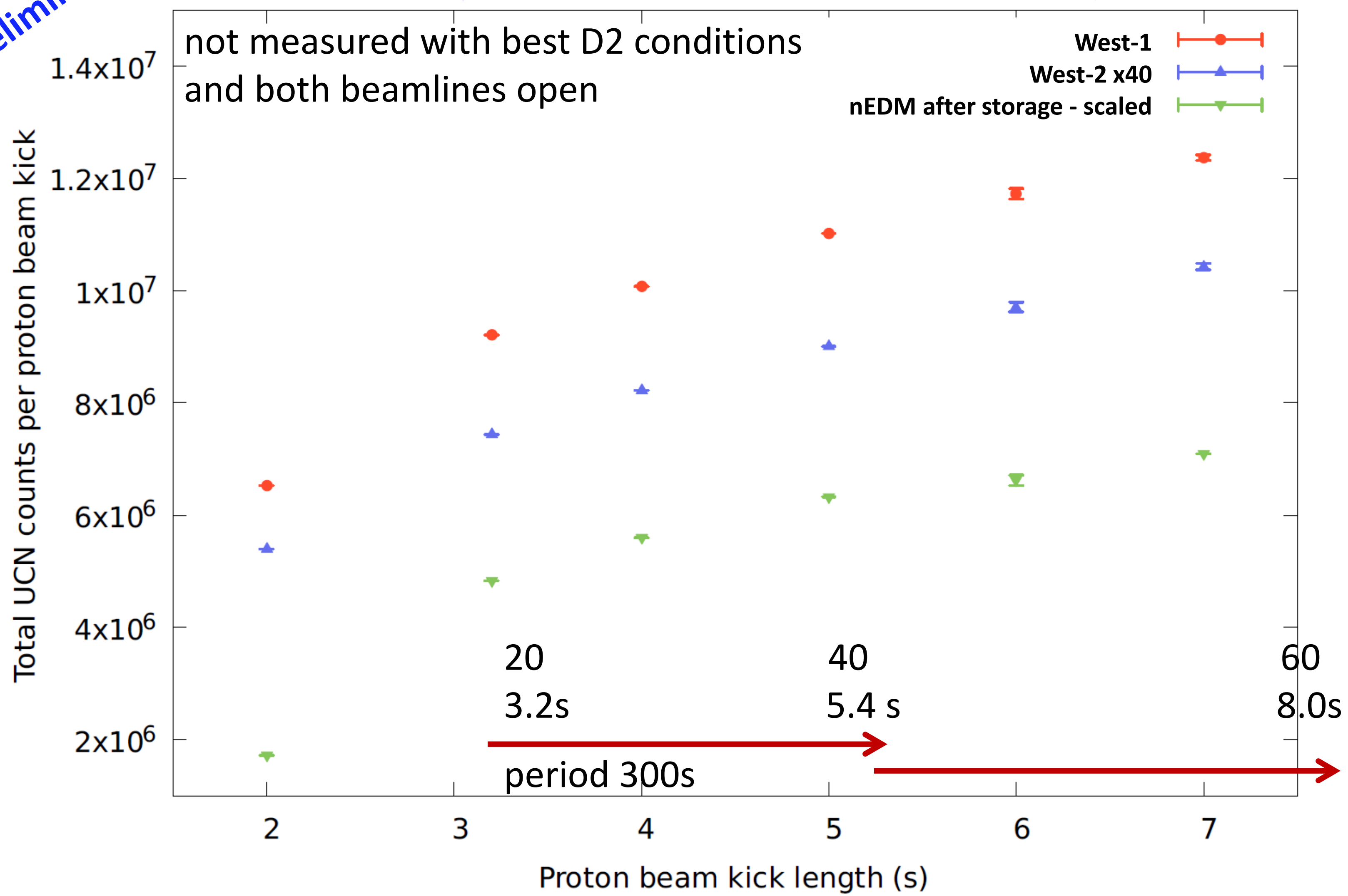
UCN operations in 2015
increasing duty cycle 20→40μA



increasing duty cycle 20→40μA → 60μA in 2016

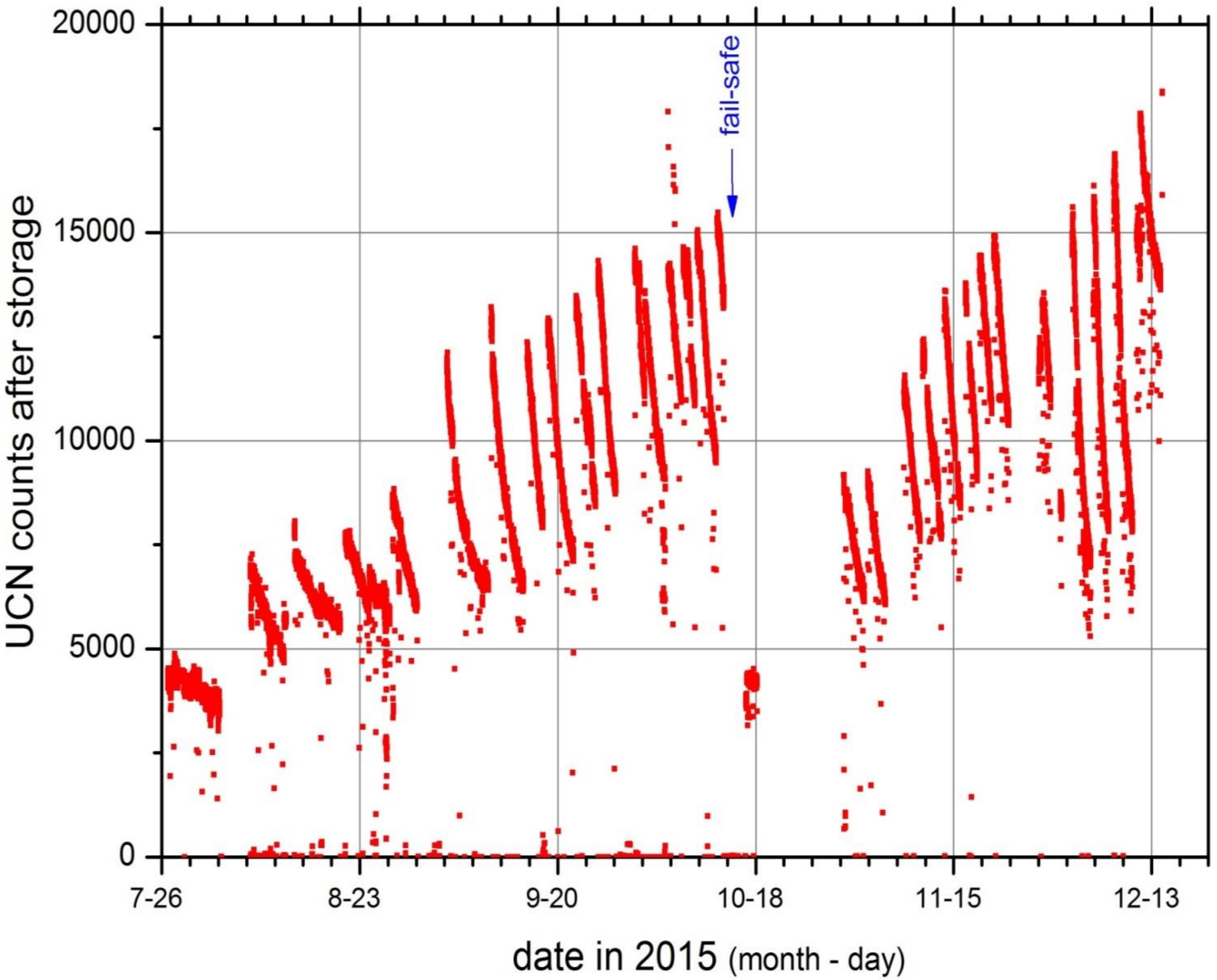
change pulse length or frequency

preliminary



plot cortesy D.Ries

UCN monitoring over entire operating period using nEDM detector

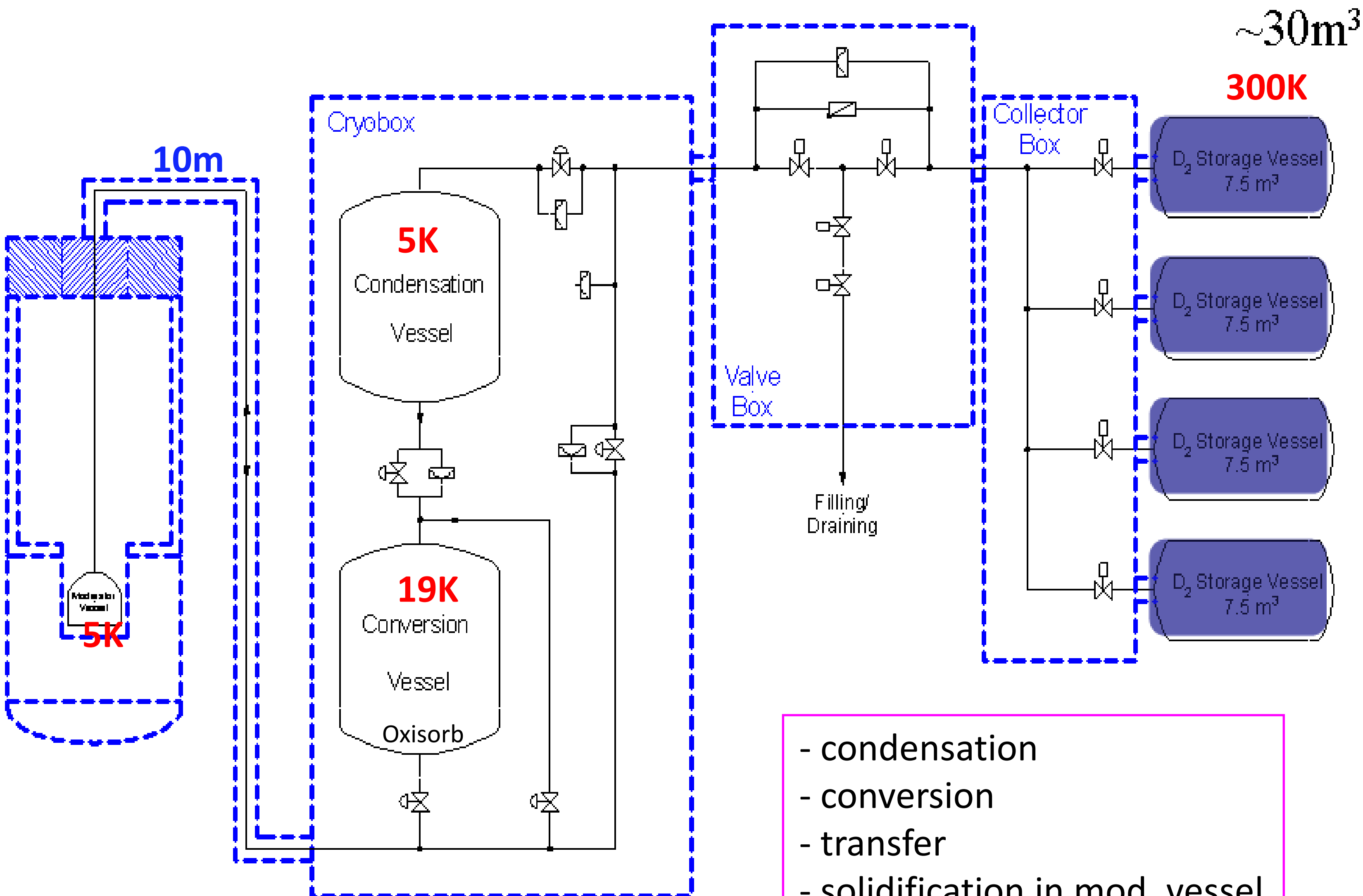


Measurement of the total UCN counts (spin-up and -down) after 180s of storage in the nEDM precession chamber

Main features:

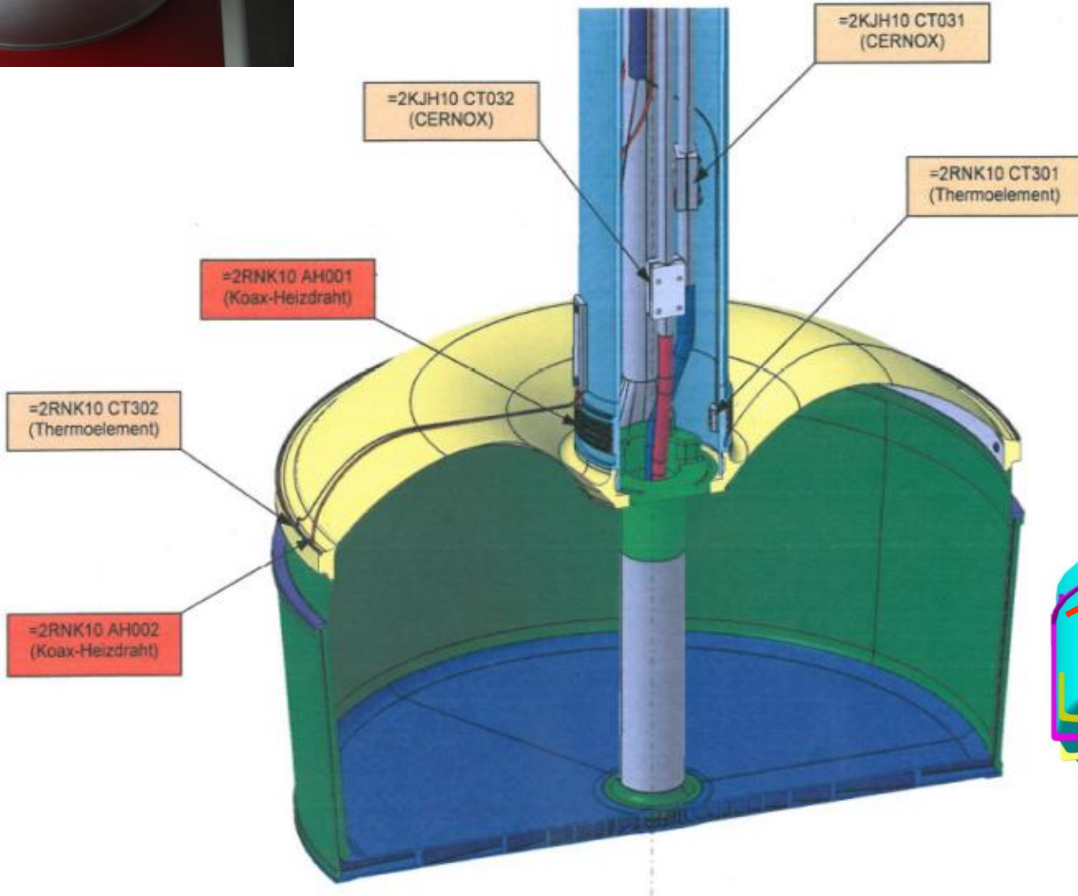
- **operation / failsafe**
- **continuous UCN output increase over operating period**
- **UCN output decrease over short time and regain of UCN output after conditioning**

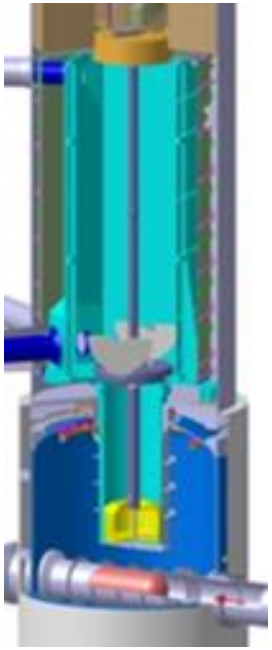
Sketching preparation of solid deuterium

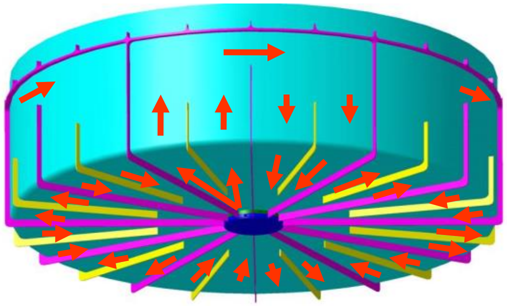


- condensation
- conversion
- transfer
- solidification in mod. vessel

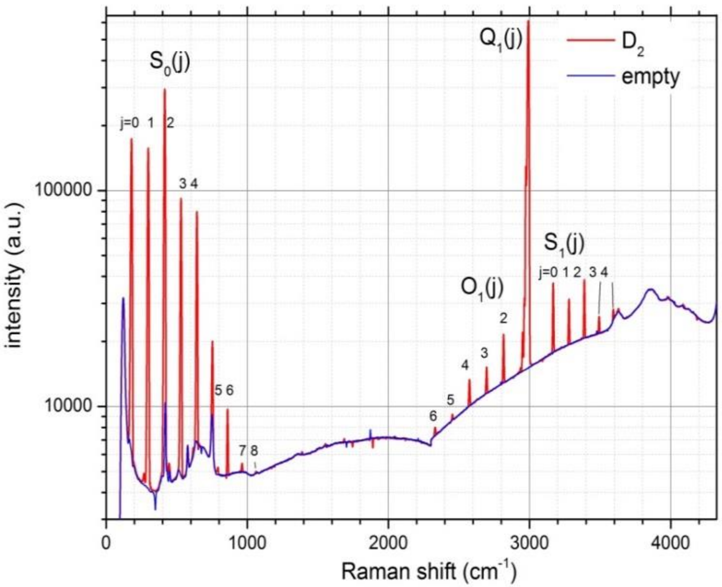
solid D2 vessel

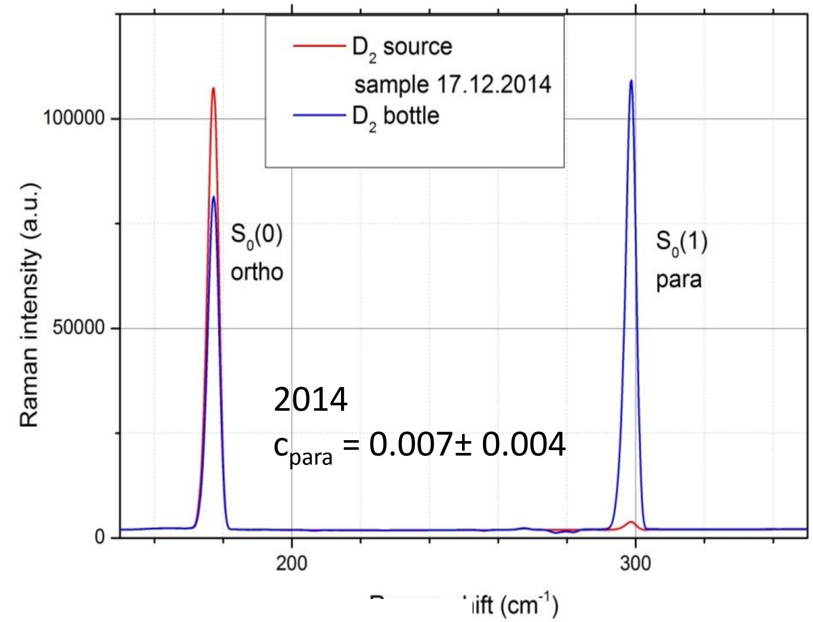


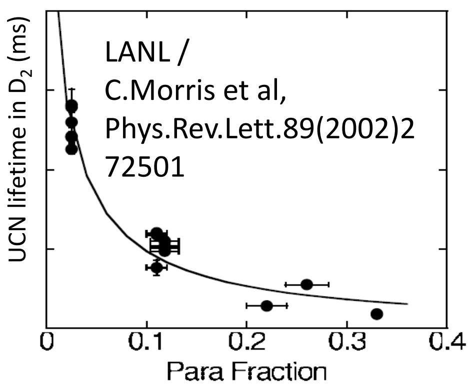


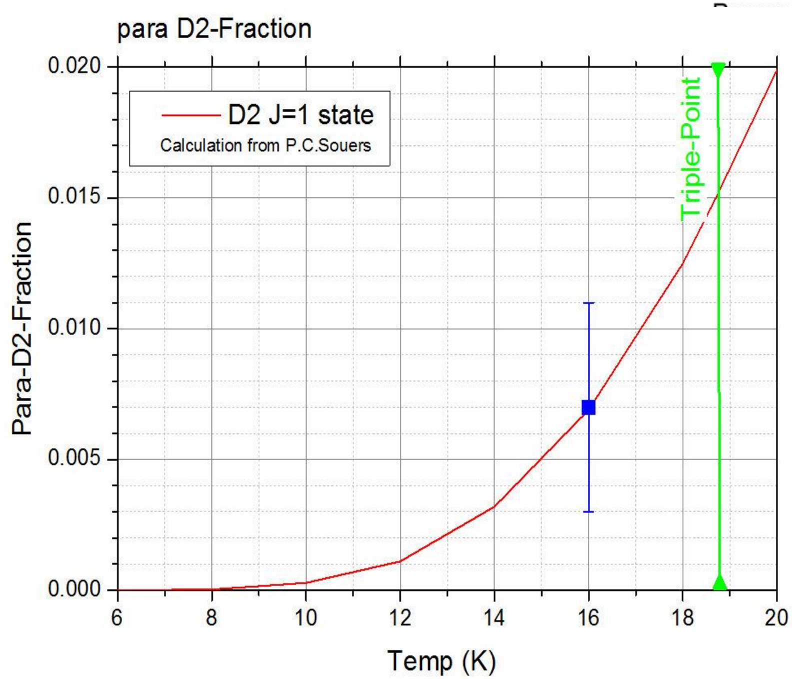


Raman spectroscopy







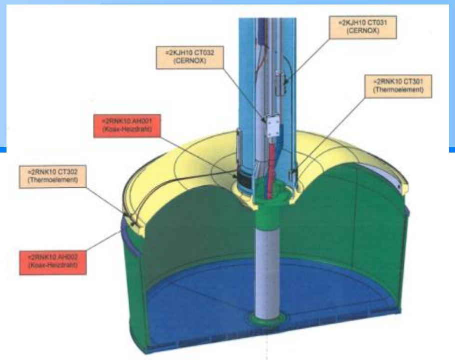


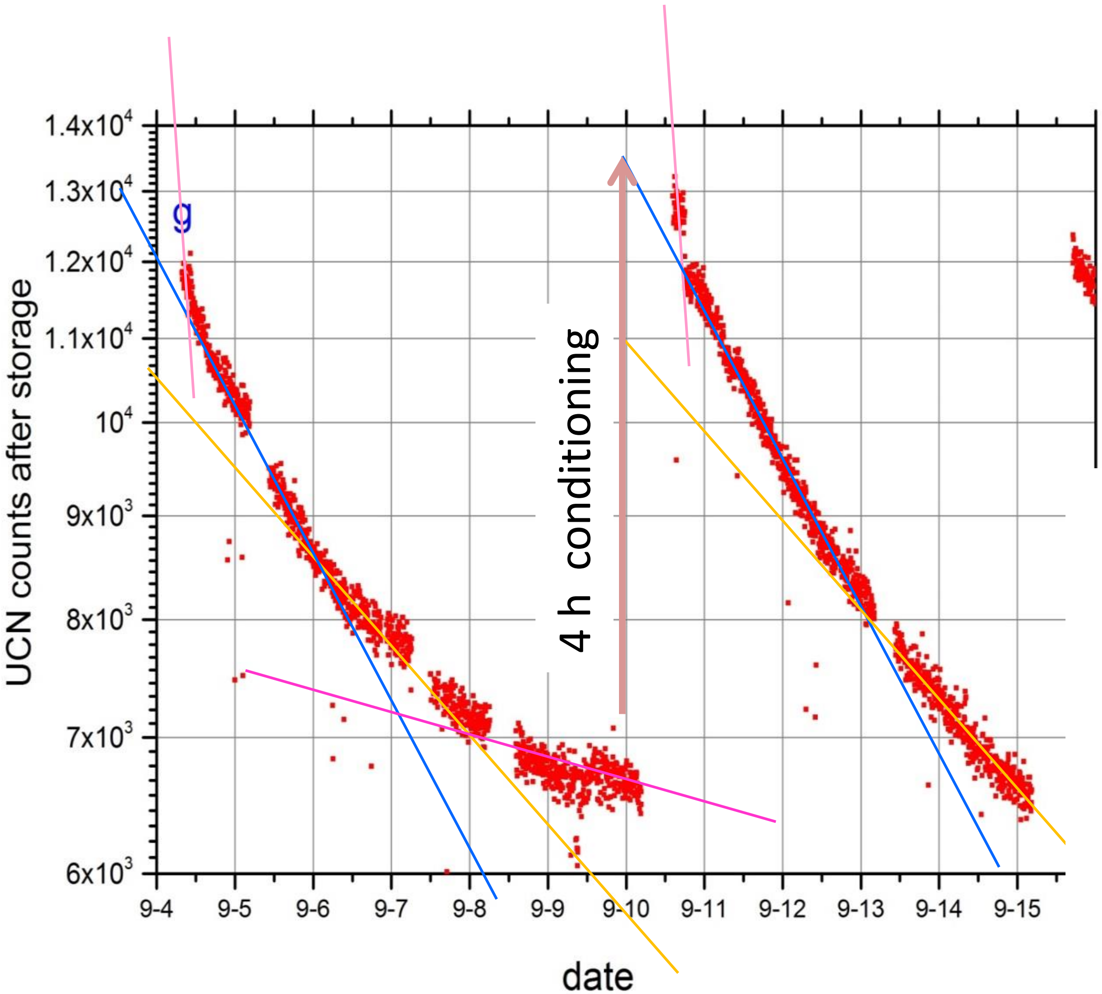
2015 (preliminary)

c_{Para} = 0.007 +- 0.003

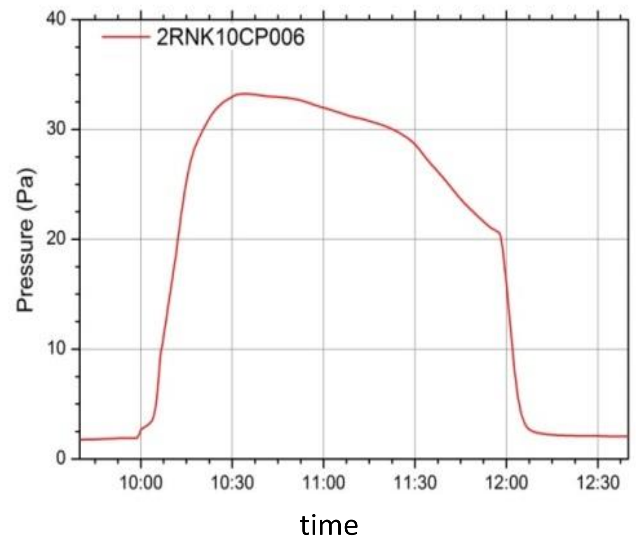
consistent value with 2014

short D2 conditioning to regain UCN intensity decrease while operating



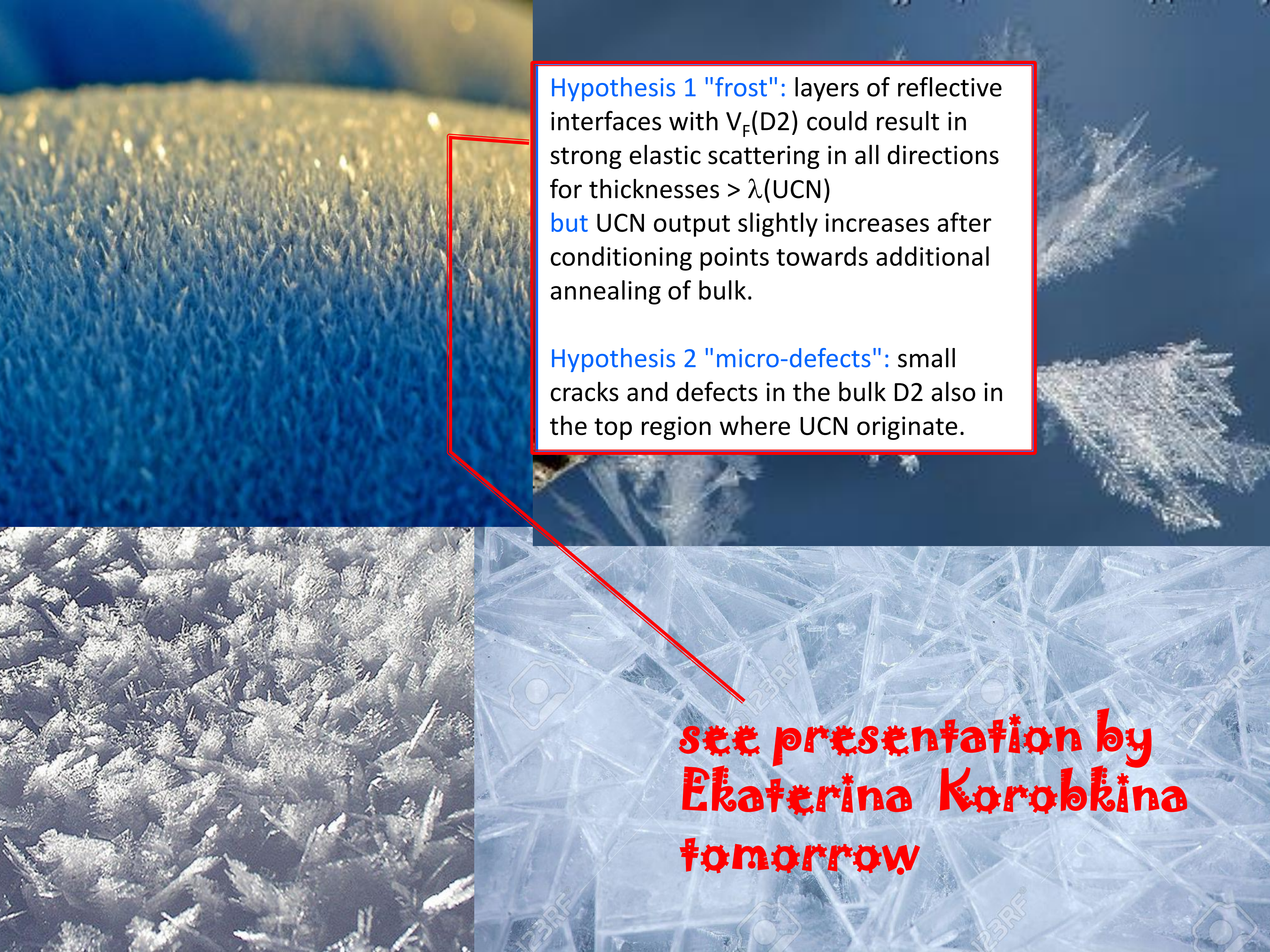


pressure measured in moderator vessel above solid D2

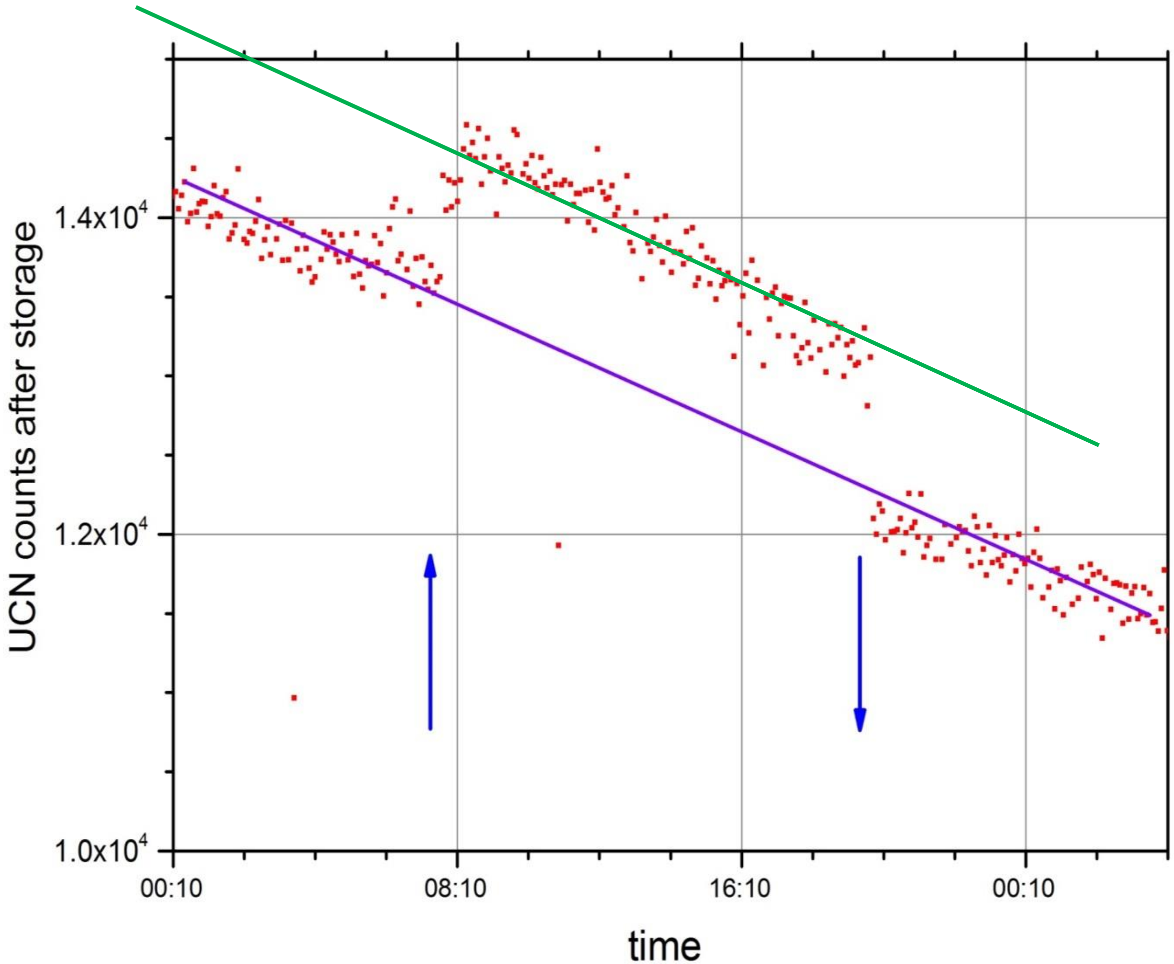


higher UCN output → faster rate decrease

- not a single exponential
- regain of UCN output always worked


Hypothesis 1 "frost": layers of reflective interfaces with V_F(D2) could result in strong elastic scattering in all directions for thicknesses > λ(UCN)
but UCN output slightly increases after conditioning points towards additional annealing of bulk.
Hypothesis 2 "micro-defects": small cracks and defects in the bulk D2 also in the top region where UCN originate.
see presentation by Ekaterina Korobkina tomorrow

high (2.4mA) proton beam current day



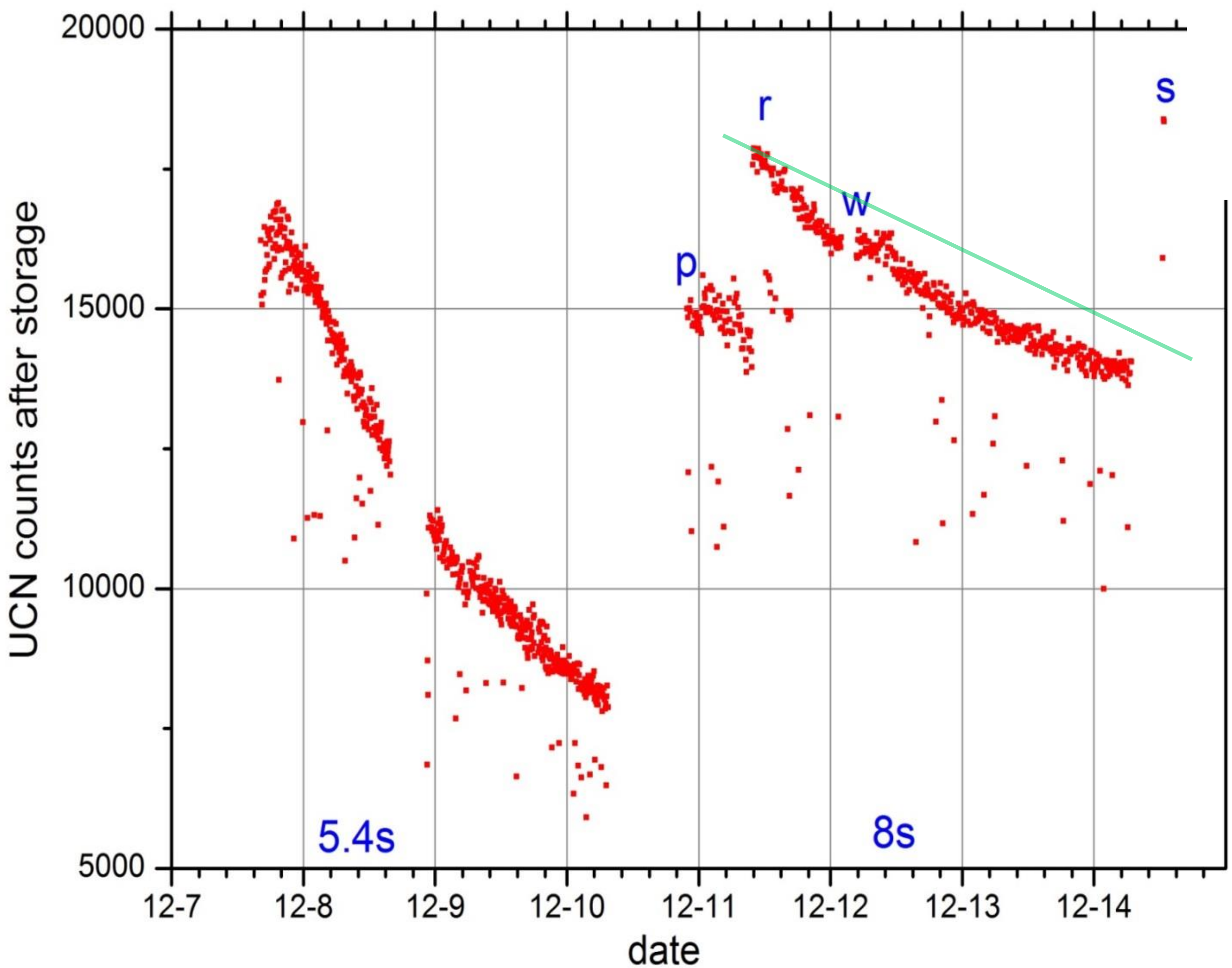
- UCN intensity increase linear with proton beam current

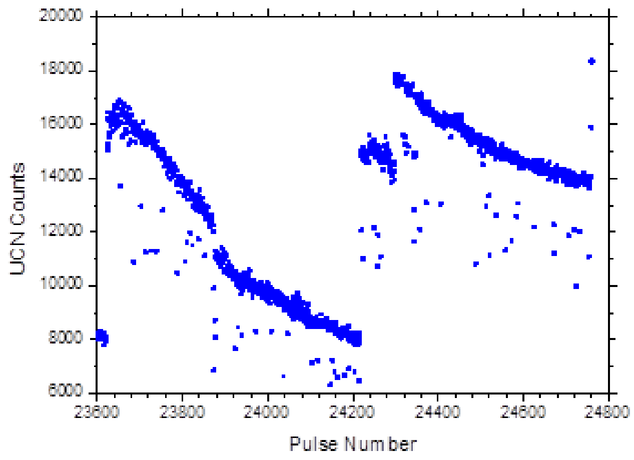
- at this pulse sequence (4.1s every 300s) the UCN intensity decreased faster at 2.4 mA in comparison to 2.2 mA standard operating current

- slower decrease rate was regained with lower beam current

→ this hints at a beam power dependent effect on the UCN output

Increasing proton pulse length: 5.4s to 8s

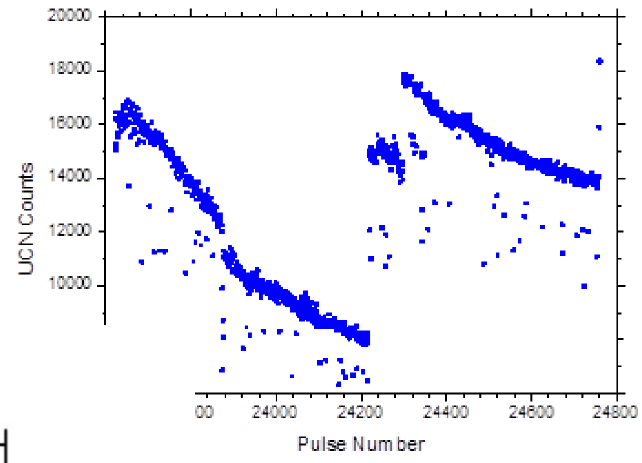


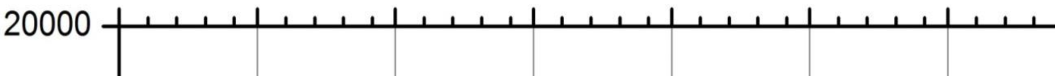


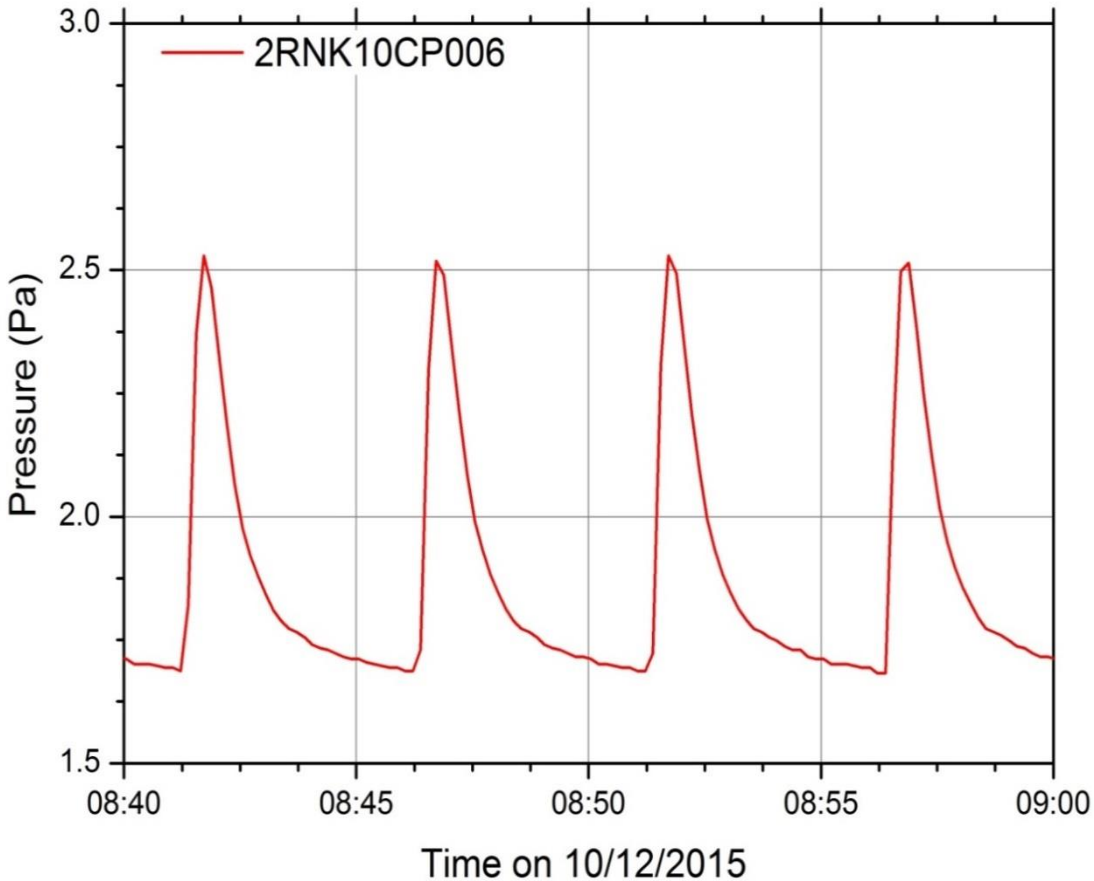
after 4h conditioning full regain of UCN output
→ conditioning works also when solid D2 deteriorated with 8s long pulses
a different slope in UCN intensity decrease is visible

p, r) shutter W-1 closed - open

Increasing proton pulse length: 5.4s to 8s



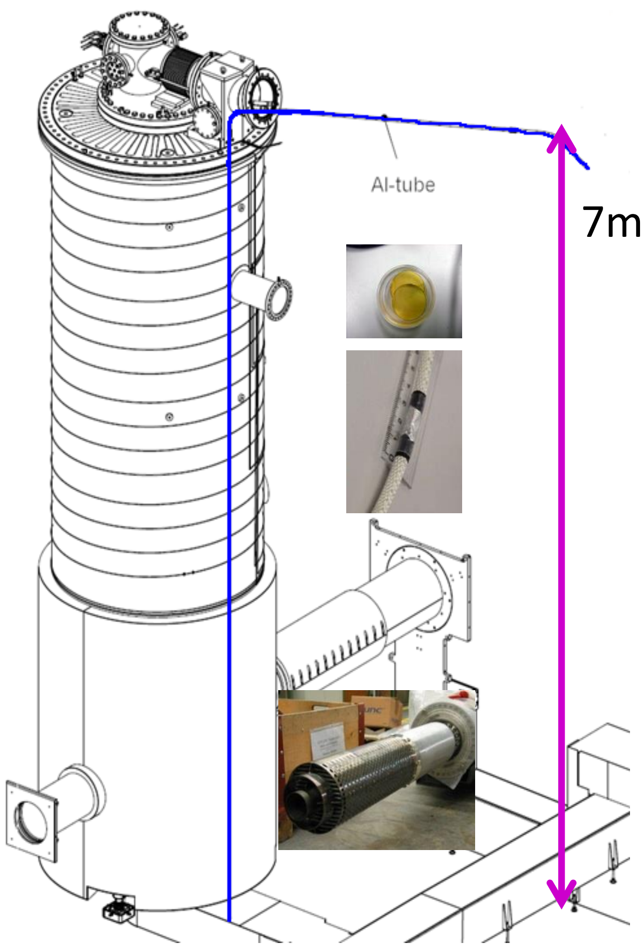




D2 vapor pressure shows cooling works also fine at higher duty cycle

Check of various sub-systems of the UCN source

Confirmation of target assembly, proton beam and neutron flux



Nuclear Instruments and Methods in Physics Research A 777 (2015) 20–27

Contents lists available at ScienceDirect

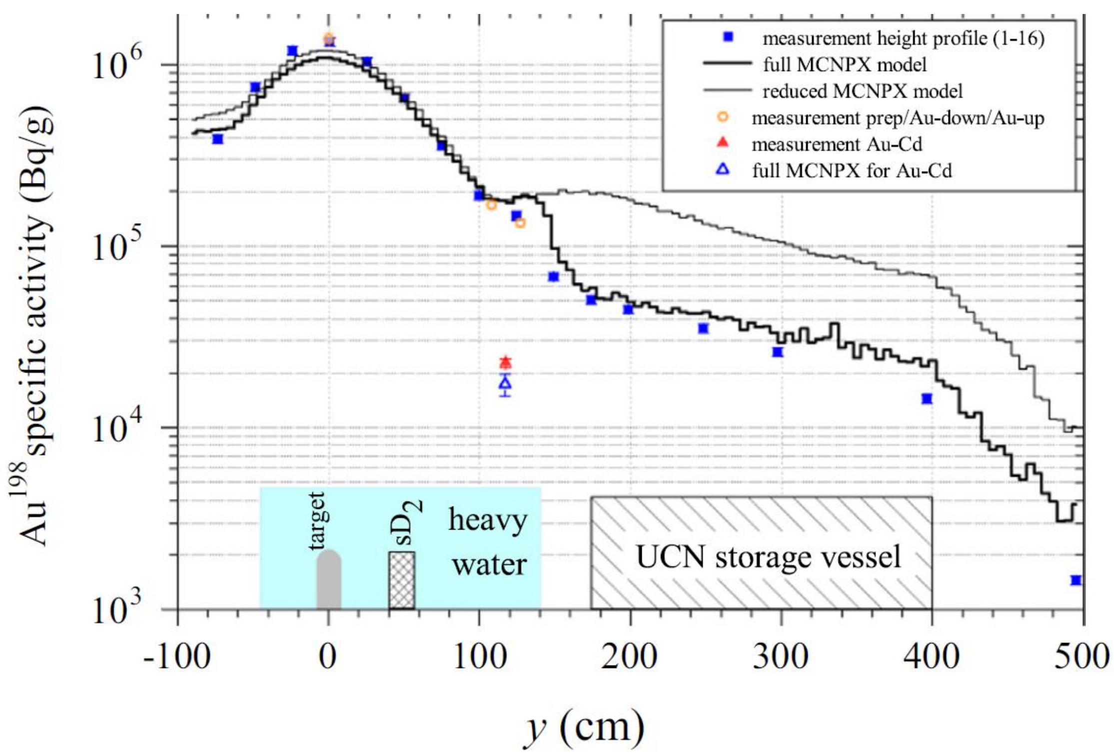
Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

Neutron production and thermal moderation at the PSI UCN source

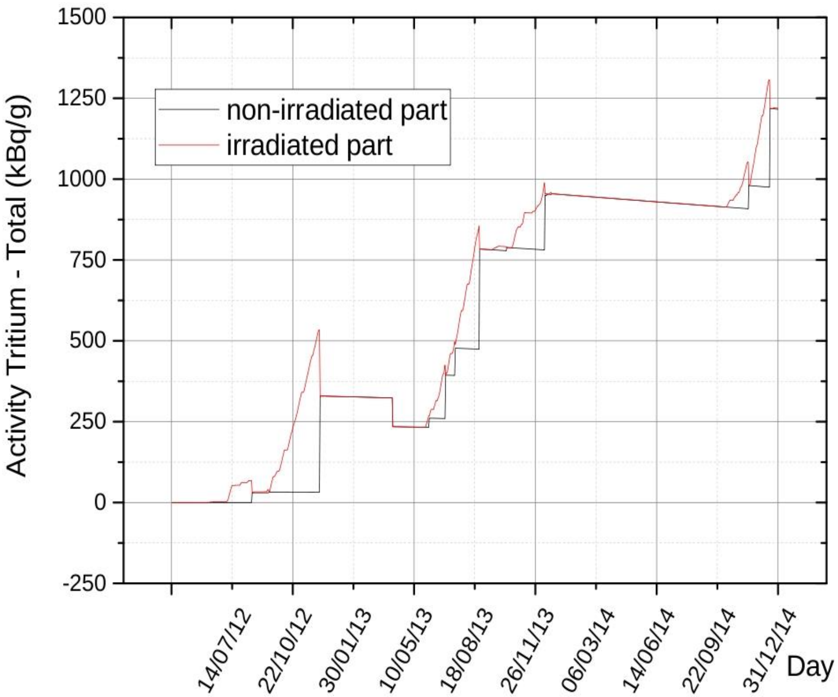
H. Becker [a,b], G. Bison [a], B. Blau [a], Z. Chowdhuri [a], J. Eikenberg [a], M. Fertl [a], K. Kirch [a,b], B. Lauss [a,*], G. Perret [a], D. Reggiani [a], D. Ries [a], P. Schmidt-Wellenburg [a], V. Talanov [a,*], M. Wohlmuther [a], G. Zsigmond [a]

[a] Paul Scherrer Institute, CH-5232 Villigen PSI, Switzerland
[b] Institute for Particle Physics, Eidgenössische Technische Hochschule, Zürich, Switzerland



Cold neutron flux from MCNP simulation and experimental determination via tritium activation

Calculated history of tritium inventory
in the source D2



capture cross-section depends on neutron energy
→ T content is sensitive to neutron energy spectrum

- determine T/D in gas D2 via AMS

and

- T/D in D_2O produced via fuel cell

-> up to now only rough agremeent between the two methods (AMS might be complicated)

Ion Beam Physics, ETH Zurich — Annual report 2014

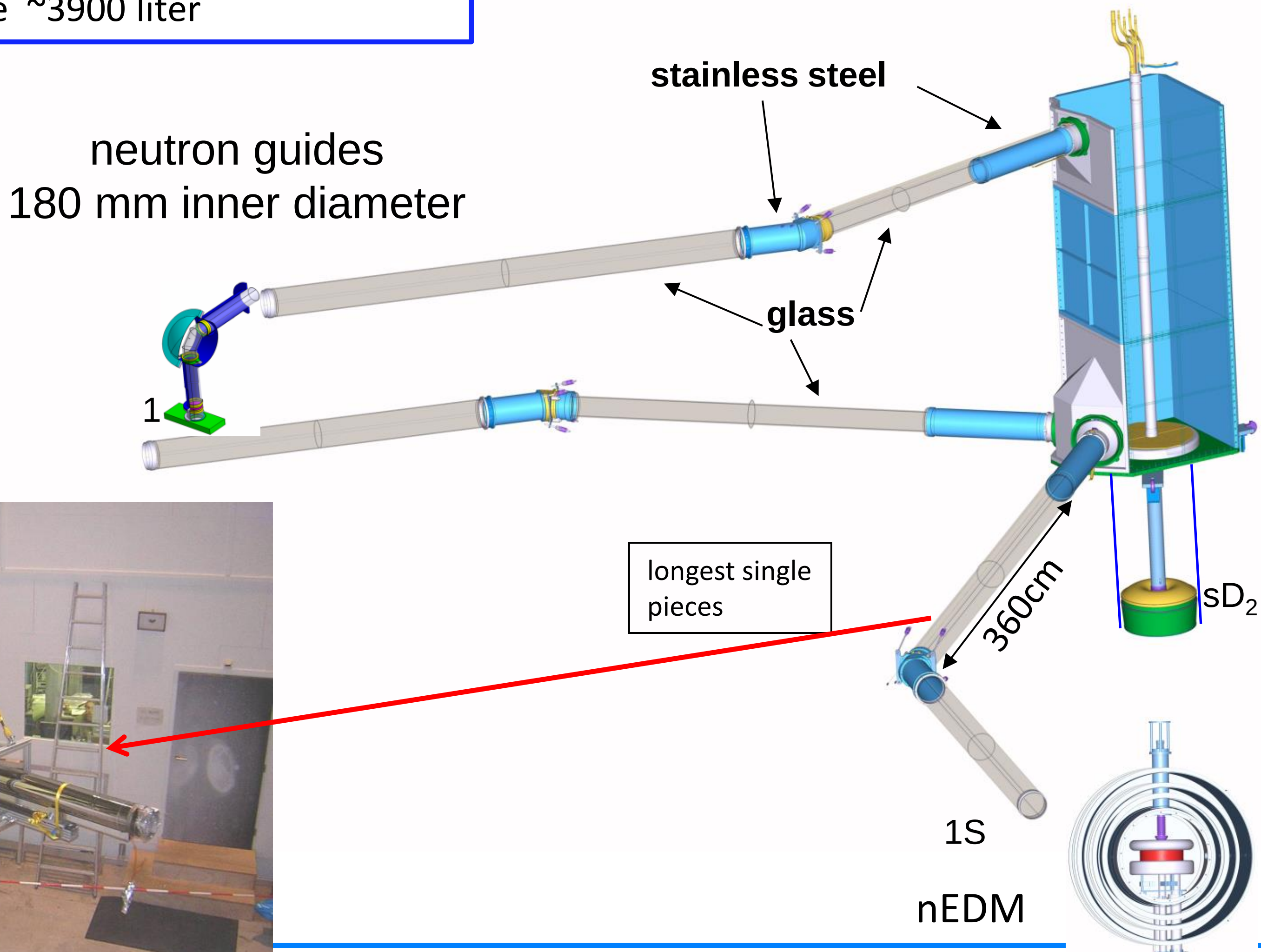
FIRST TRITIUM TO DEUTERIUM RATIOS BY AMS AT LIP

Neutron flux measurement via tritium production in deuterium

H. Becker[1], K. Kirch[1,2], B. Lauss[2], D. Ries[1,2], M. Döbeli, L. Wacker

UCN guides with high transmission

- about 8m length each to each port
- about 10m^2 NiMo coated guide surface
- guide volume ~3900 liter



UCN transmission measured at PF2 (ILL) before mounting

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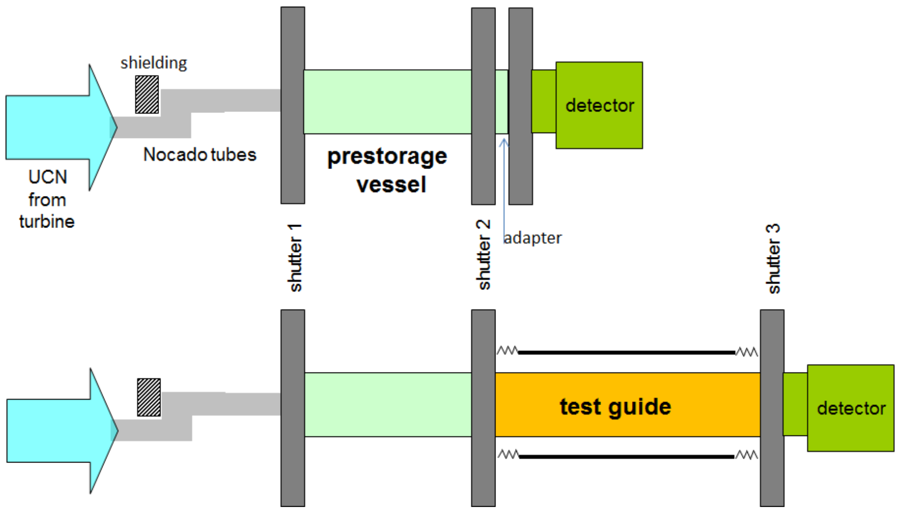

Guide name	Total transmission	Transmission per meter
1W1	0.968(1)(12)	0.988(1)(12)
1W2	0.980(2)(12)	0.991(2)(12)
2W1	0.968(1)(12)	0.980(1)(12)
1S1	0.946(3)(12)	0.986(3)(12)
1S2	0.999(1)(12)	0.999(1)(12)
1S3	0.975(1)(12)	0.959(1)(12)

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Nuclear Instruments and Methods in Physics Research A

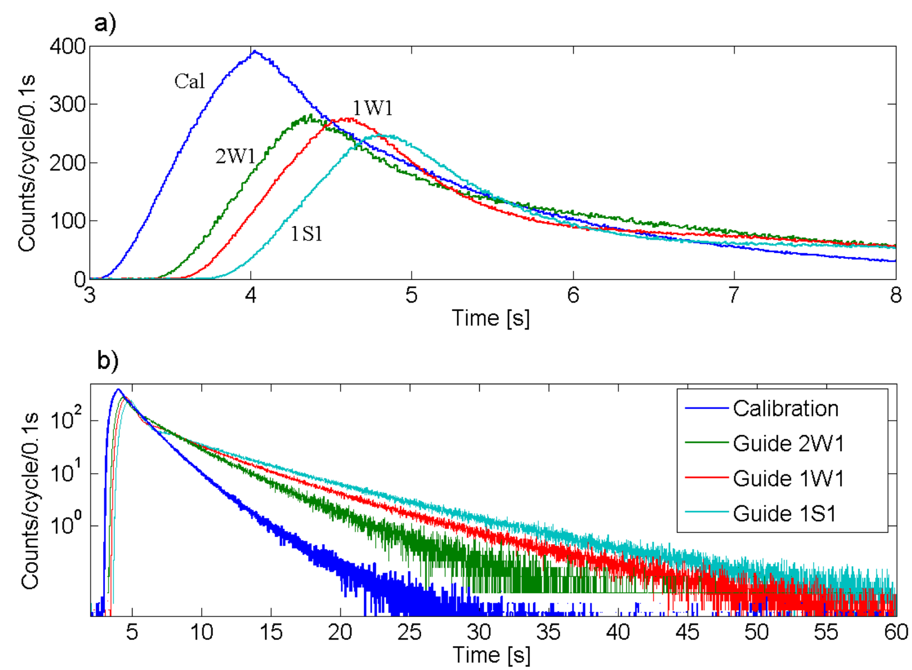
journal homepage: www.elsevier.com/locate/nima

ELSEVIER

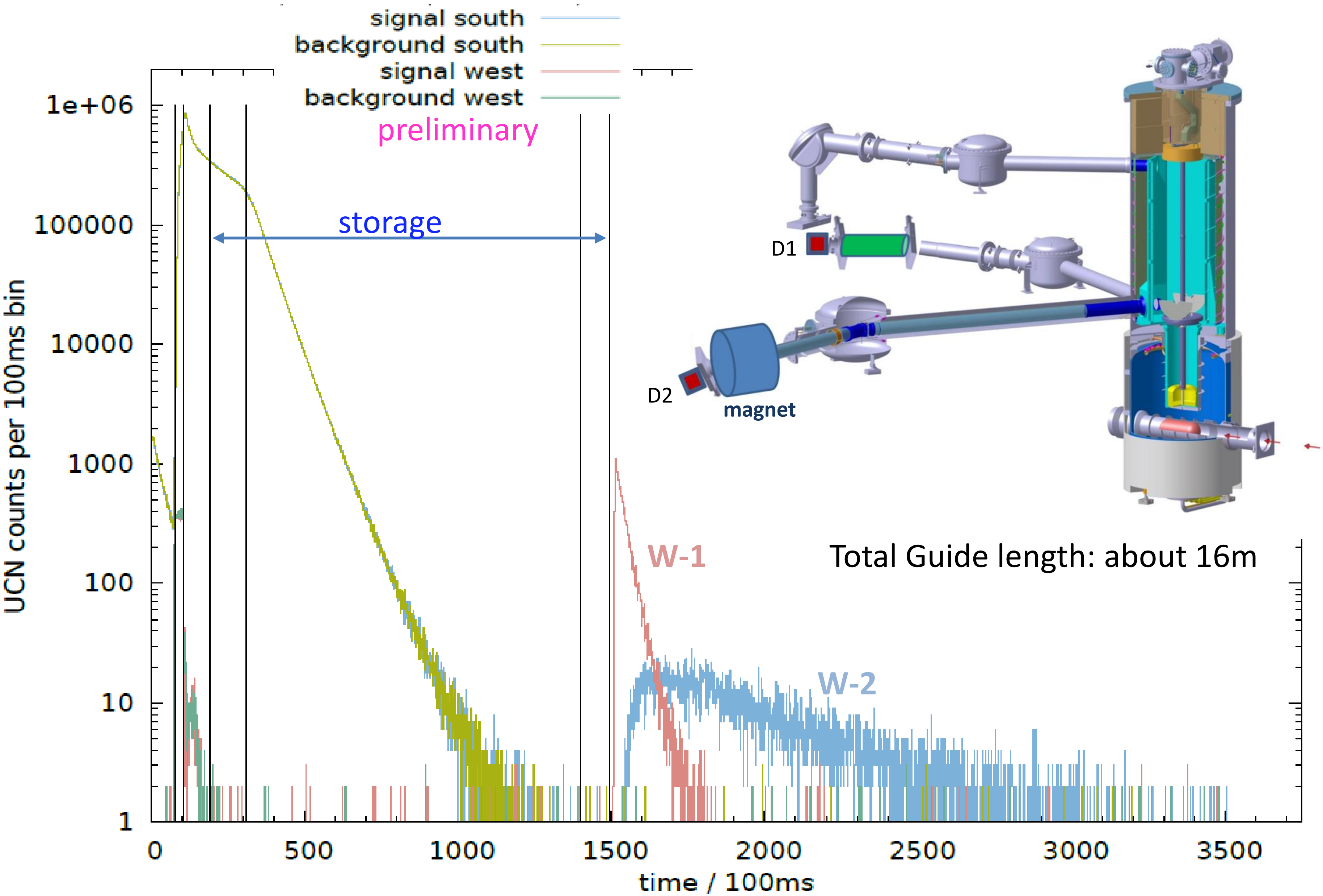
A prestorage method to measure neutron transmission of ultracold neutron guides

B. Blau [a], M. Daum [a], M. Fertl [a,b,1], P. Geltenbort [c], L. Göltl [a,b], R. Henneck [a], K. Kirch [a,b], A. Knecht [a], B. Lauss [a,*], P. Schmidt-Wellenburg [a], G. Zsigmond [a]

[a] Paul Scherrer Institute (PSI), CH-5232 Villigen PSI, Switzerland
[b] Institute for Particle Physics, Eidgenössische Technische Hochschule (ETH), Zürich, Switzerland
[c] Institute Laue-Langevin (ILL), 71 avenue des Martyrs, F-38000 Grenoble, France



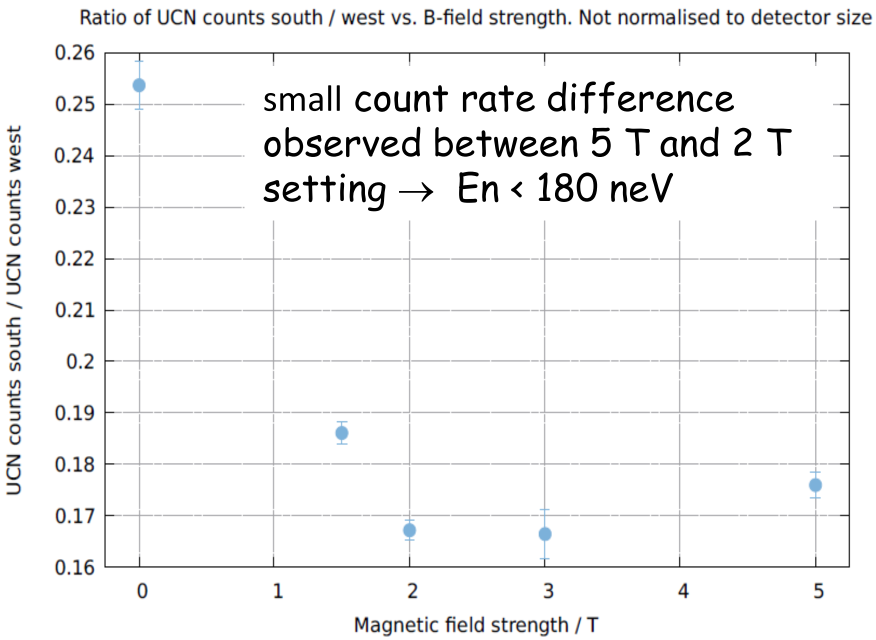
UCN Ping-Pong to test transport in guides, storage vessel, windows

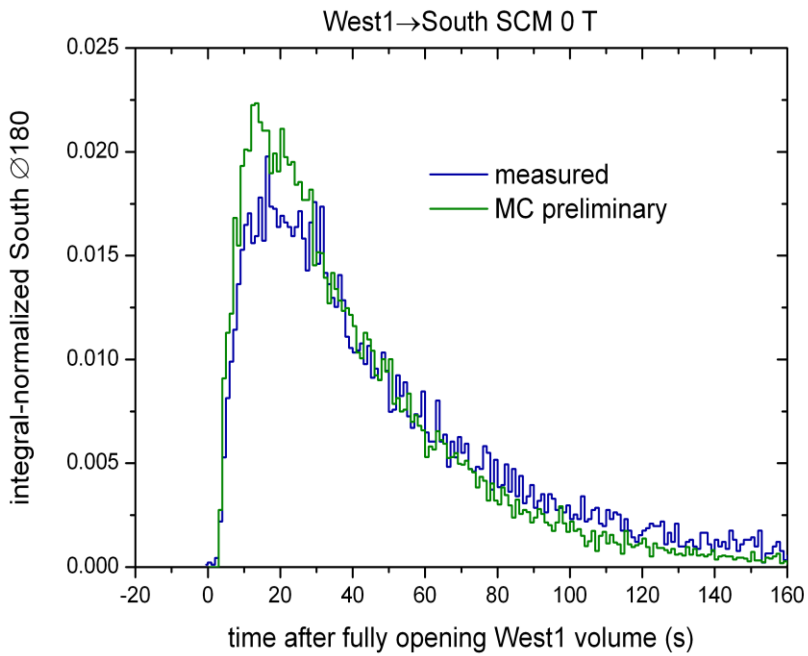


Total Guide length: about 16m

Ping Pong - UCN arrival times: simulation matches measurement

preliminary





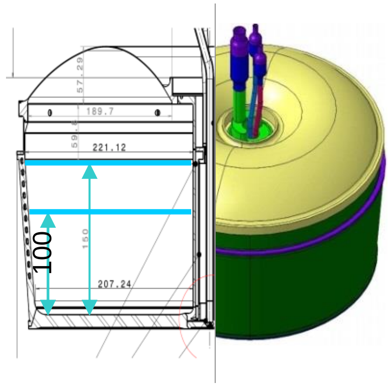
➔ full simulation reproduces measurements rather well working on further improvements

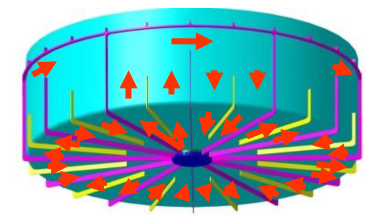
➔ no 'big' unknowns in storage vessel or guides

A 'calibrated' source of UCN
UCN production in solid thin-film D2

D2 fills with gas → exact D2 mass known (p,T)
→ freeze to make a solid thin-film D2 source

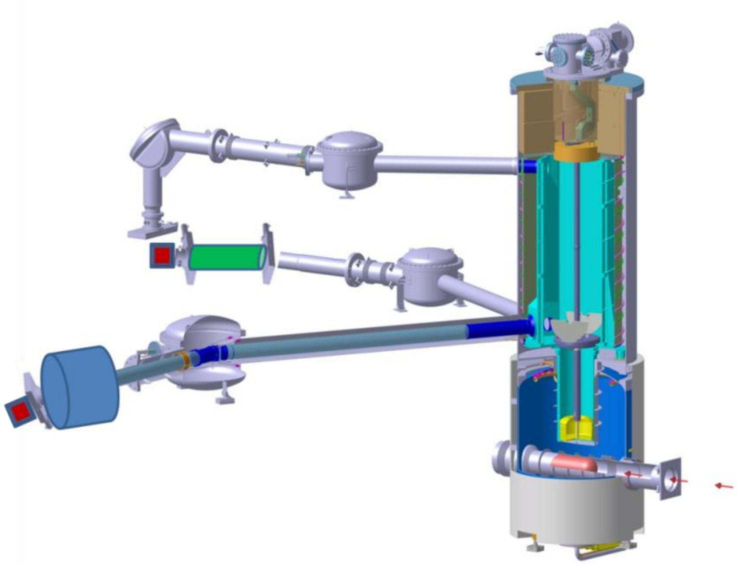
3 - 250 gram targets → thicknesses up to a few mm



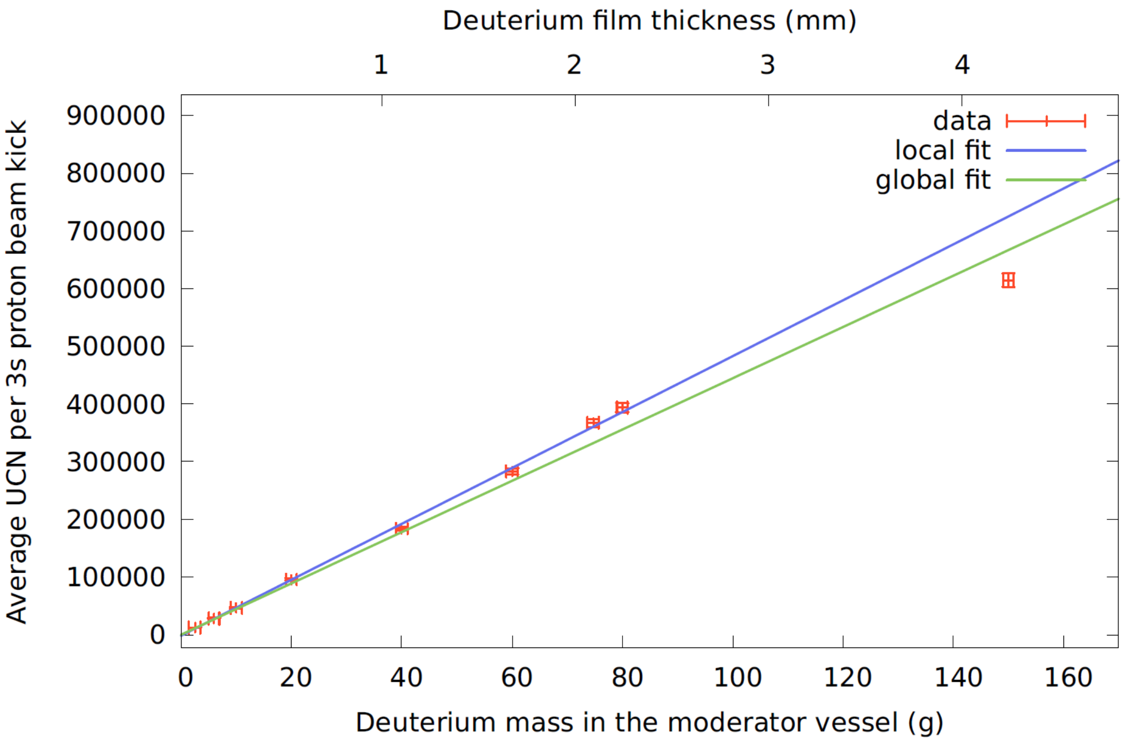


→ no UCN losses occurring within the solid D2
(lifetime is long enough that UCN exit also after multiple scattering)

- established thermal flux
- (soon established) cold flux
- established UCN production cross-section from
Golub/Boenig 1983, Yu/Malik/Golub 1985
Atchison et al, PRC71, 2005
Atchison et al, PRL99, 2007
- established UCN transport to detector above the SV shutter (Ping Pong)

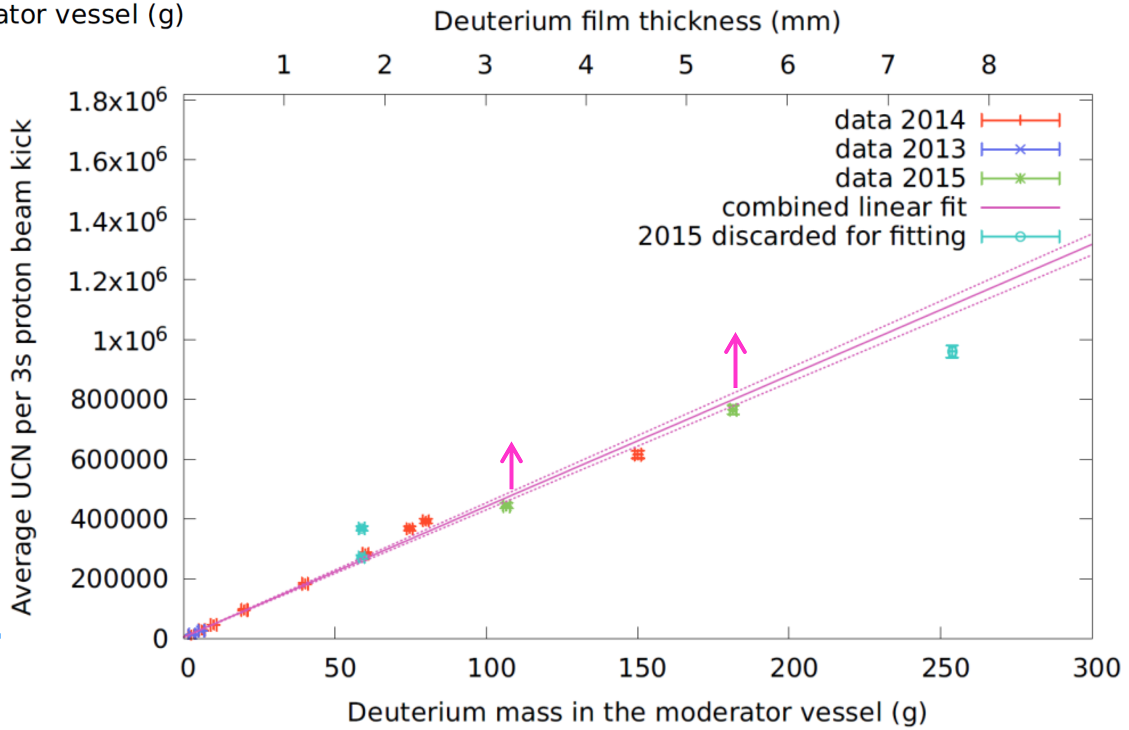


→ check UCN extraction and transport below SV shutter via thin film measurement



Ultra Cold Neutron Source

Solid thin-film D2



linear mass dependence found for similar solid D2 preparation

2015 data > 100 g : remelting improves UCN output also in thin films !

plots cortesy D.Ries

Plans for 2016

- startup of proton accelerator and UCN source beginning of May
- in 2016: main priority - deliver high UCN intensity to nEDM experiment
- improve D2 conditioning - is faster conditioning possible ?
- increase to 3% duty cycle
- further understanding of all parts of the source
- study further improvement possibilities for UCN output

many thanks to **Dieter Ries**
for his work and many plots I could show,
which are part of his PhD work.

thank you