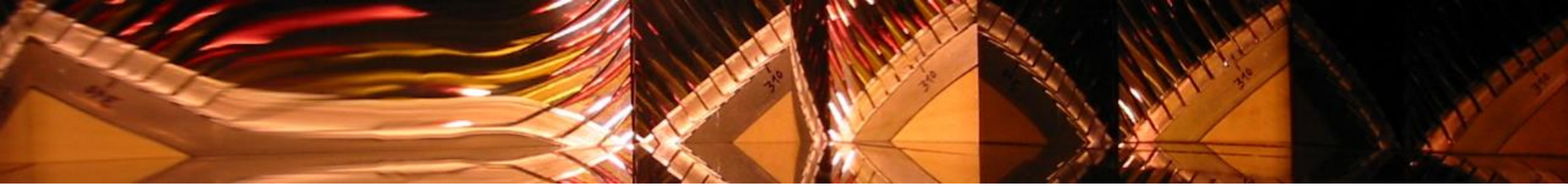
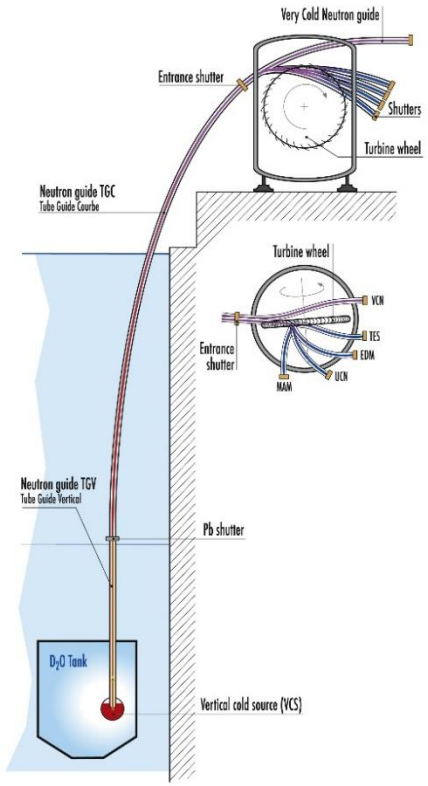


Experience with the very cold neutron source PF2/VCN at the Institut Laue-Langevin



Tobias JENKE

Institut Laue-Langevin

Workshop on Very Cold and Ultra Cold Neutron Sources for the ESS
02/02/2022

NEUTRONS FOR SOCIETY

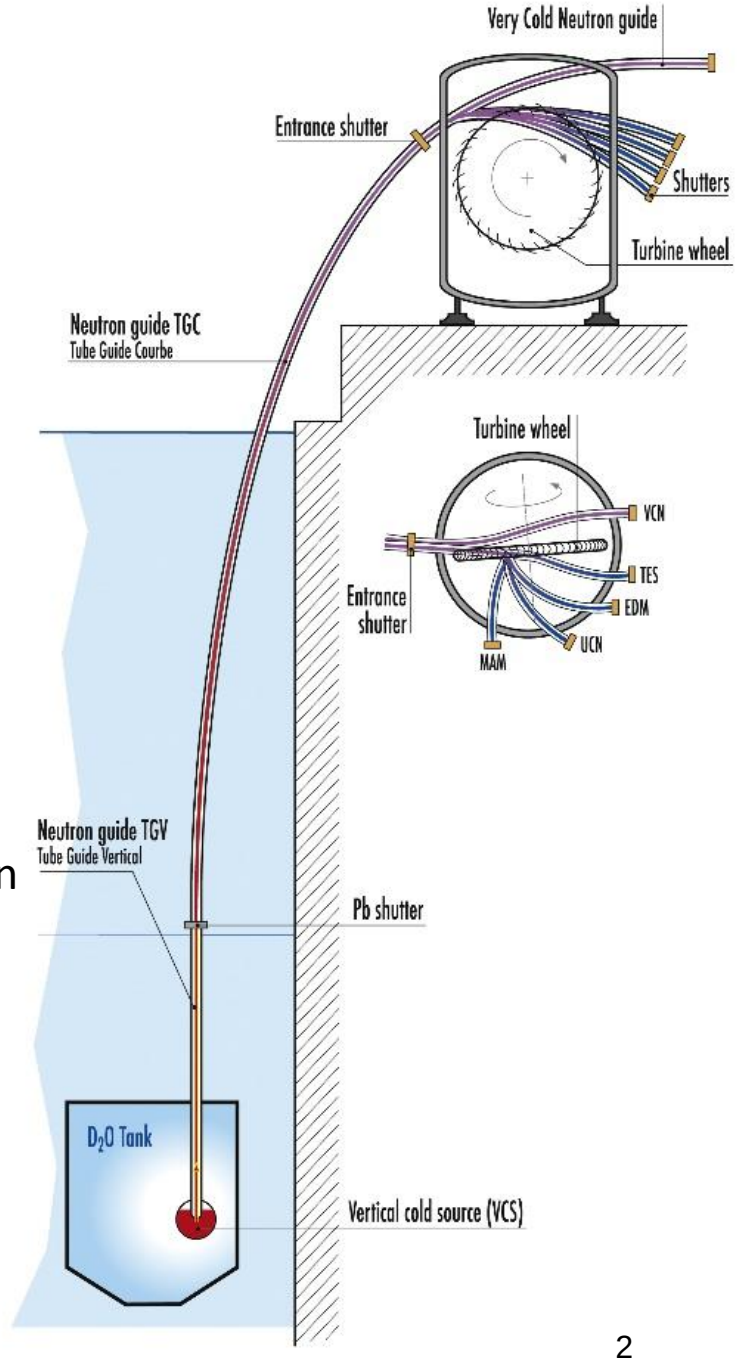
CV – Instrument PF2

« Physique Fondamentale 2 »

- Name of the instrument: PF2 („physique fondamentale 2“)
- Type of instrument: UCN and VCN source (converter)
- Age: born in 1985 (37 years old)
  Scheduled instrument since 1994 replacing PN5

- Adress: ILL5, level D
- Fathers: Albert STEYERL & Paul AGERON

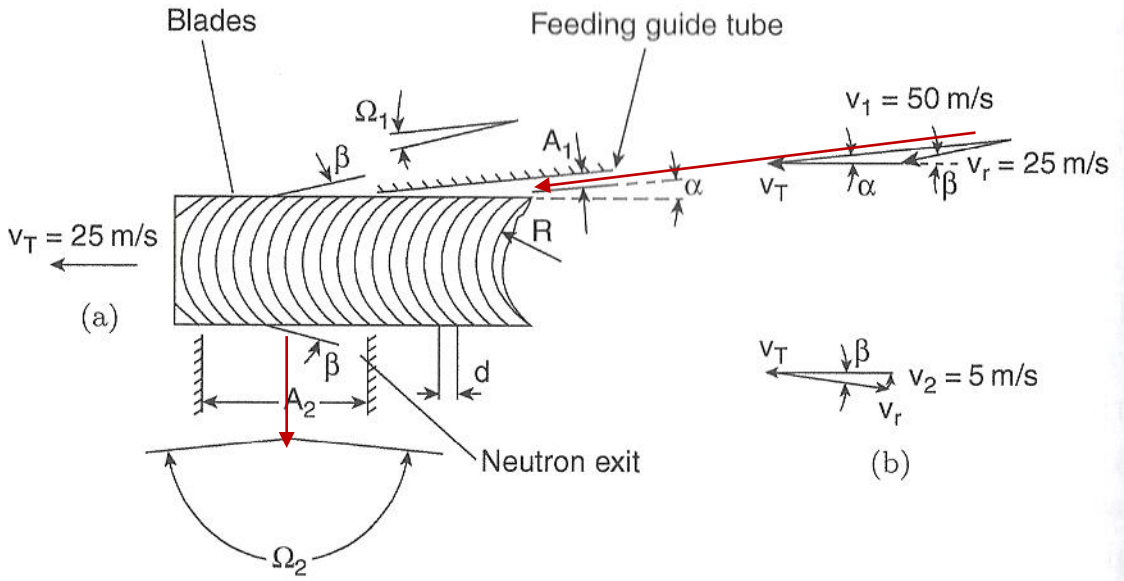
- AS was one Discoverer of UCN in 1968
  [Phys. Lett. 29B (1969) 33]
- A.S. built a device today known as „Steyerl turbine“ at TU München, installed at level D in 1985
- P.A. designed the concept to feed the turbine with neutrons



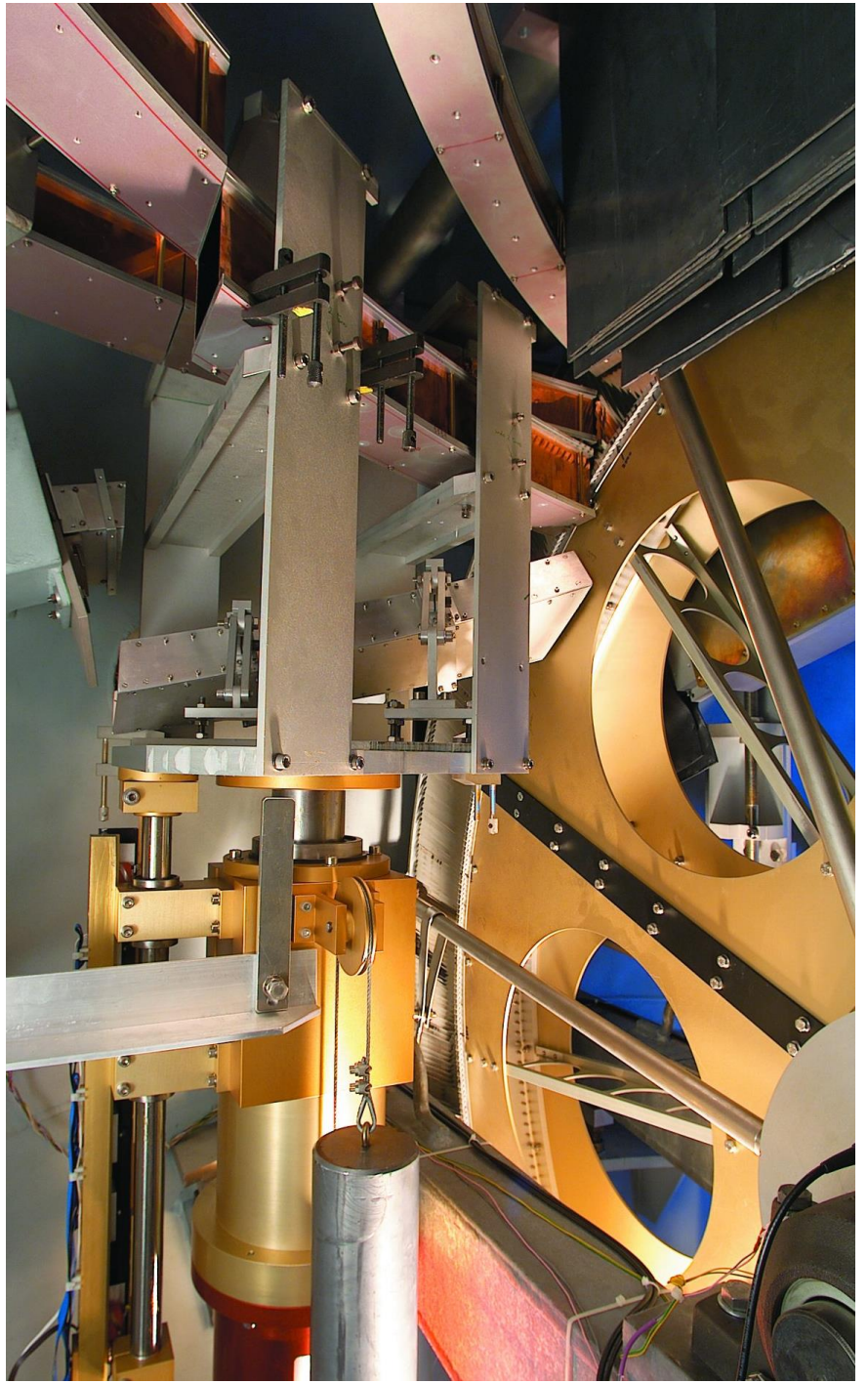
Principle of the « Neutron Turbine »

« The workhorse of UCN physics since 1985 »

- Principle of a „tennis ball stopped by a receding racket“ [A.S.]

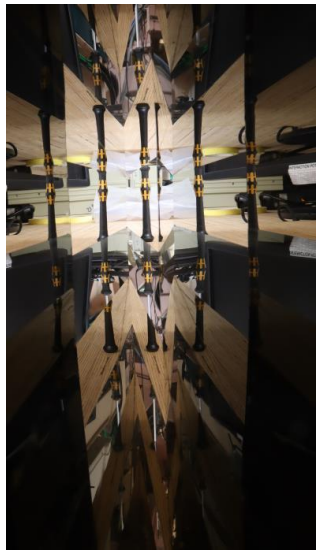


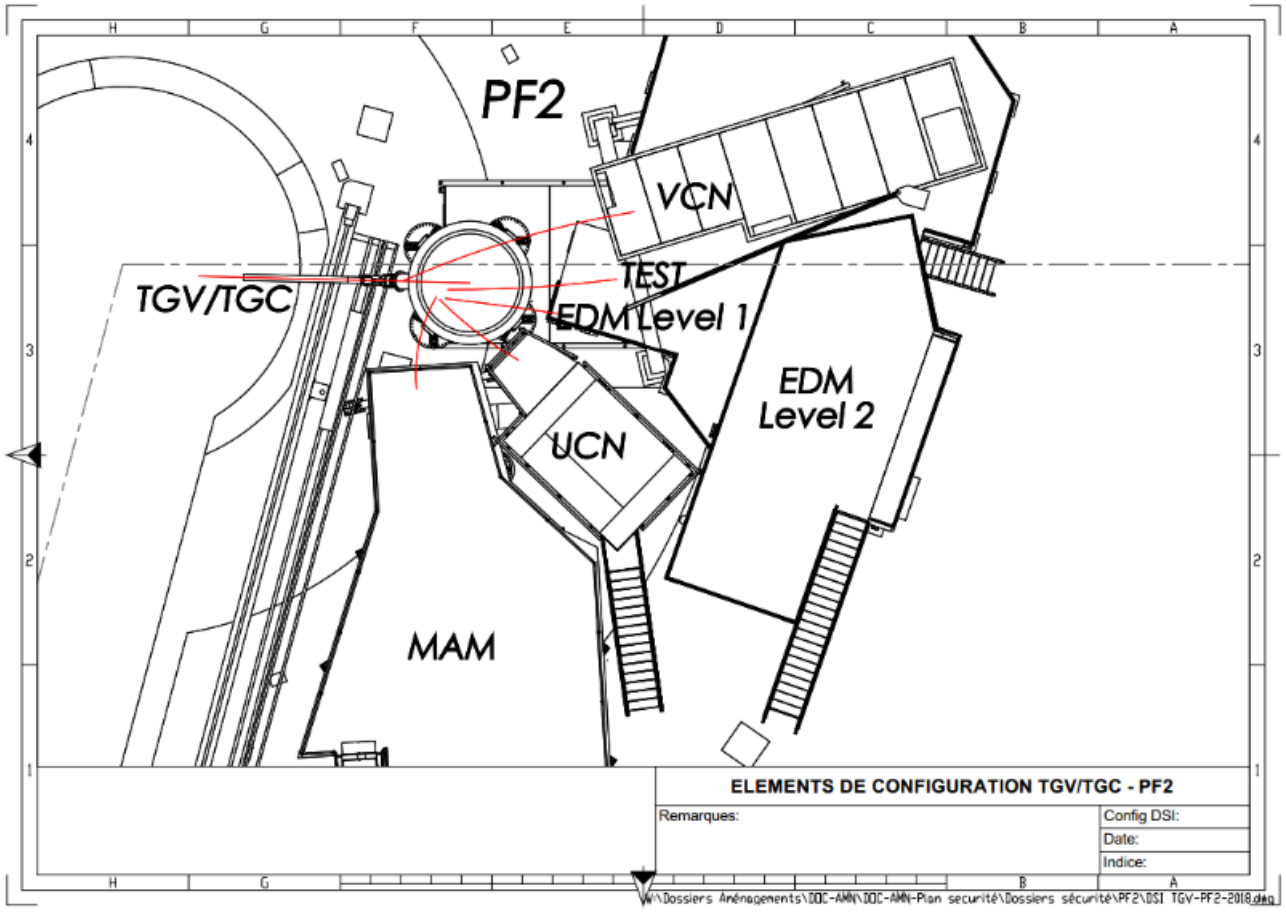
- The PF2 turbine transforms VCN with 50m/s to UCN (5m/s) by roughly 10 reflections.
- The guide section and divergence are increased by a factor of 10.

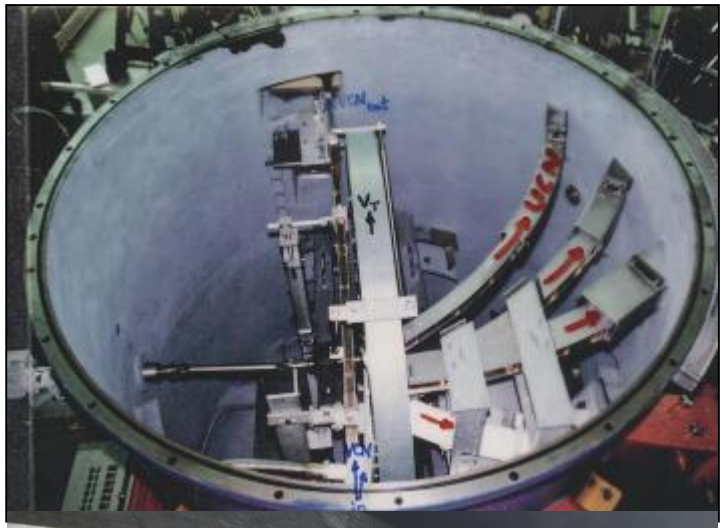


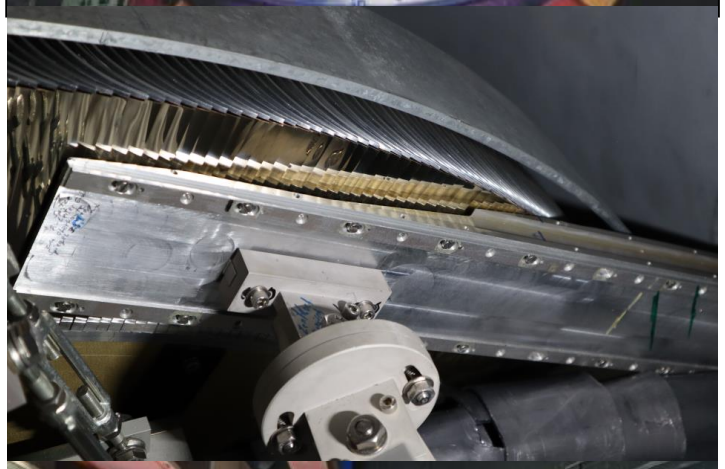
CV – Instrument *Physique Fondamentale 2*

« Physique Fondamentale 2 »







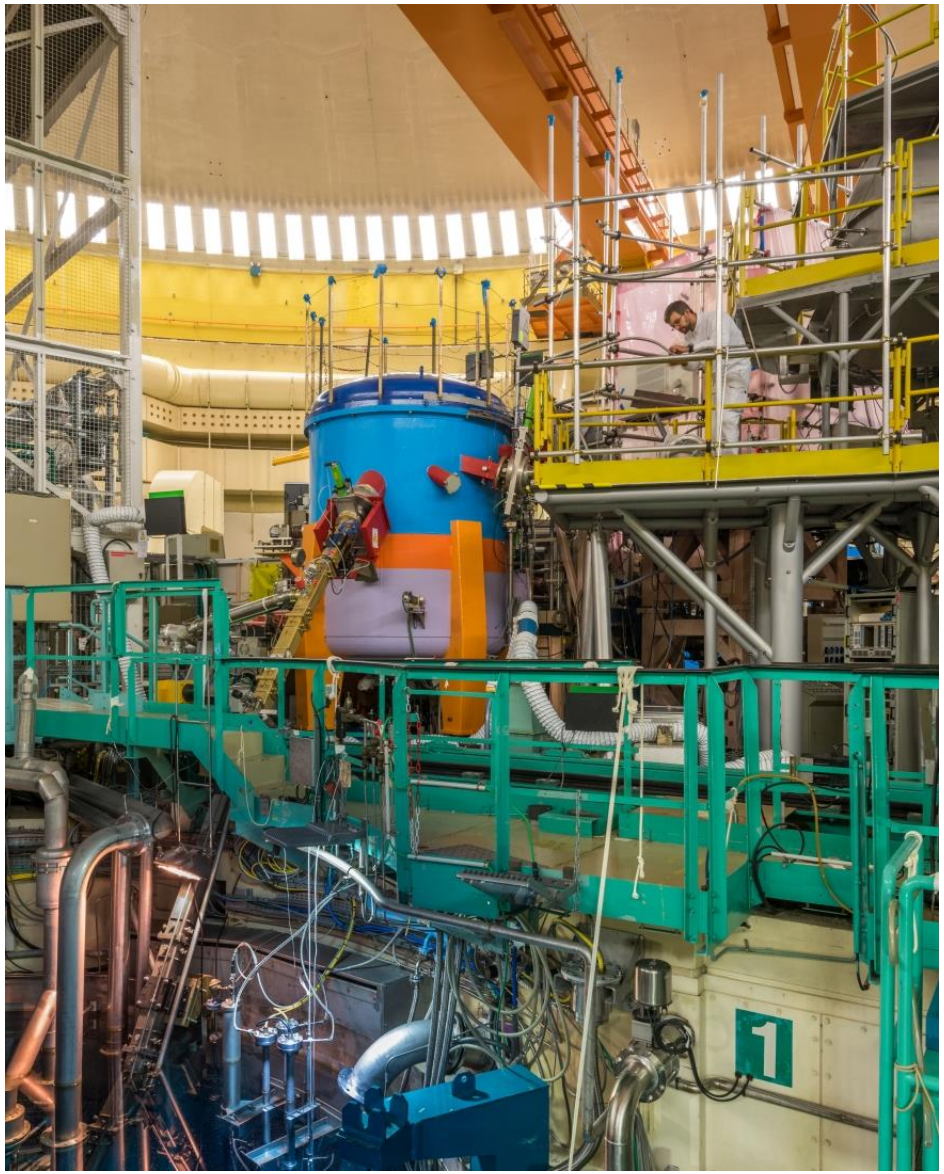


CV – Instrument *Physique Fondamentale 2*

« Physique Fondamentale 2 »

- Research Interests: fundamental properties of the free neutron

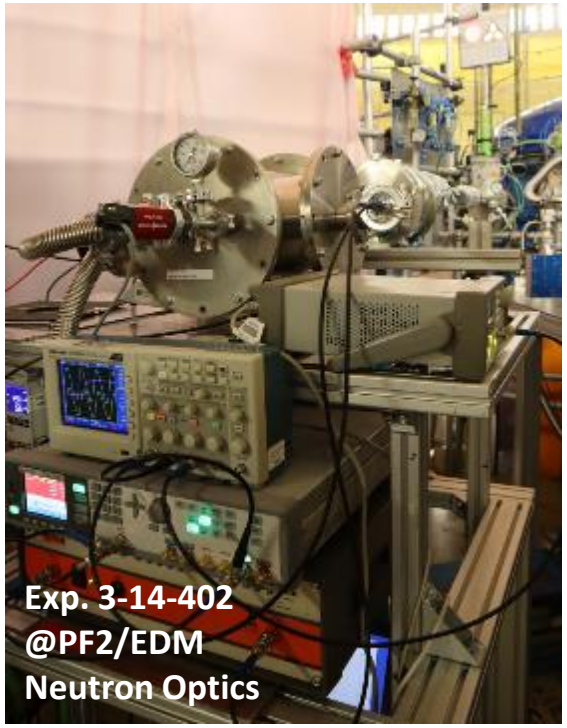
- Examples of experiments at PF2:
  - electric dipole moment of the neutron
  - various precision measurements of neutrons lifetime
  - Discovery of gravitationally bound quantum states
  - Studies of the weak equivalence principle
  - Tests of the Standard Model of Particle Physics (neutron oscillations...)
  - Advanced neutron optics and VCN optics
  - Tests of 1/v-law of cross sections

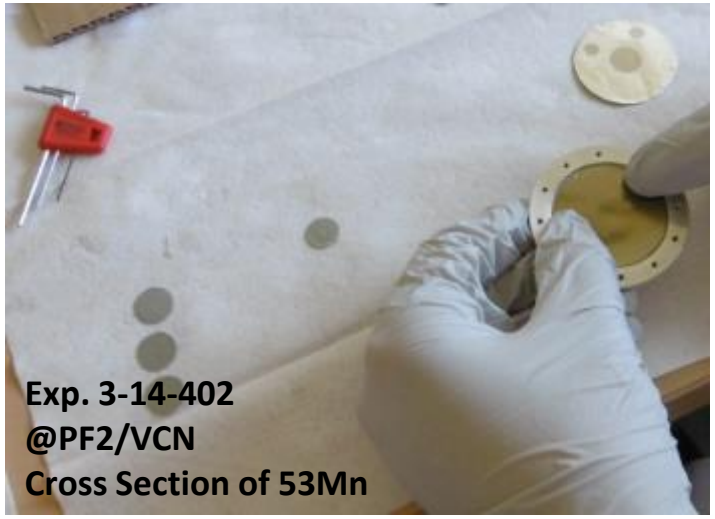


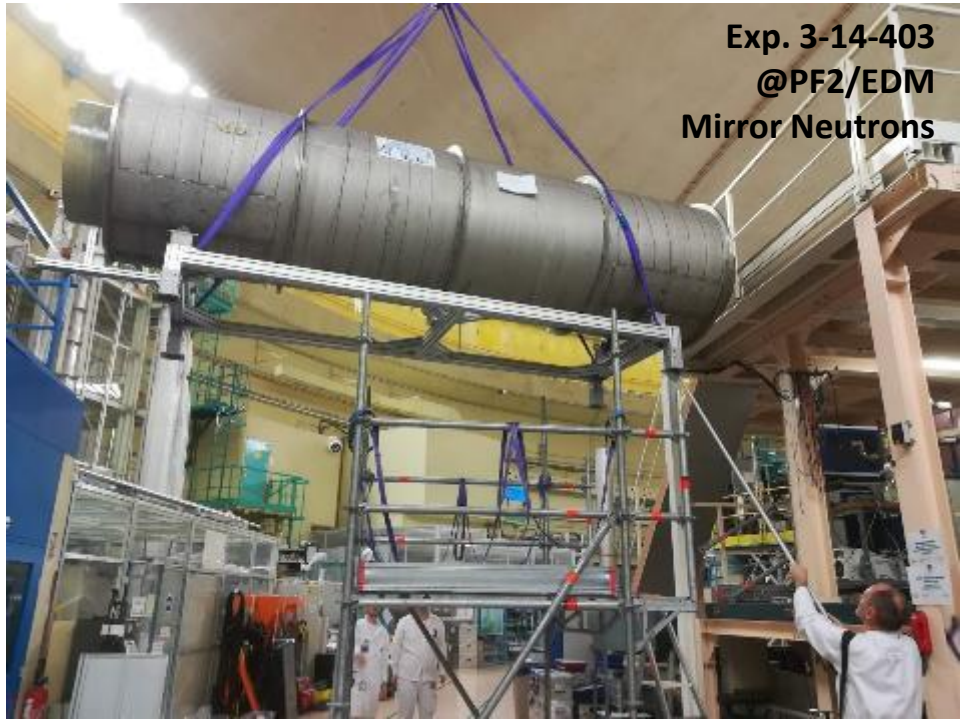
Experiments at PF2

Standard « Physics » Experiment (SPE)

- Duration: 25 days to one full cycle
- Timing: usually does not need additional backlog (can be performed in standard ILL proposal workflow)
- Equipment: variable, between 1mg sample + holder and 2 tons of equipment







Experiments at PF2

Technical Development Experiment (TDE)

- Duration: few days to 25 days
- Timing: no backlog required, standard ILL proposal workflow
- Equipment: between „1 detector“ and 1 ton of equipment


TEST-3066
@PF2/TES
„PF2-UP“


Exp. 3-14-404
@PF2/EDM
Switch for panEDM

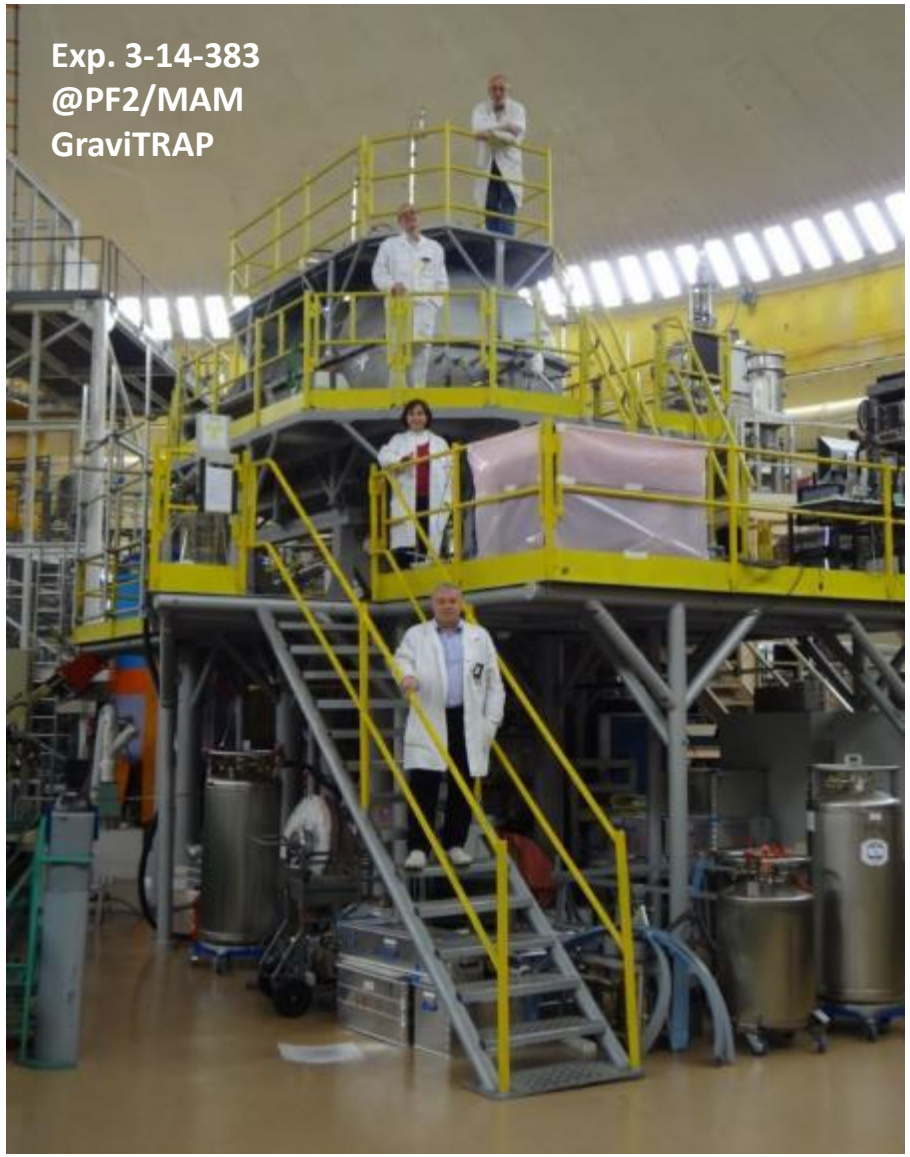

Exp. 3-14-406
@PF2/TES
„Granit Detector“

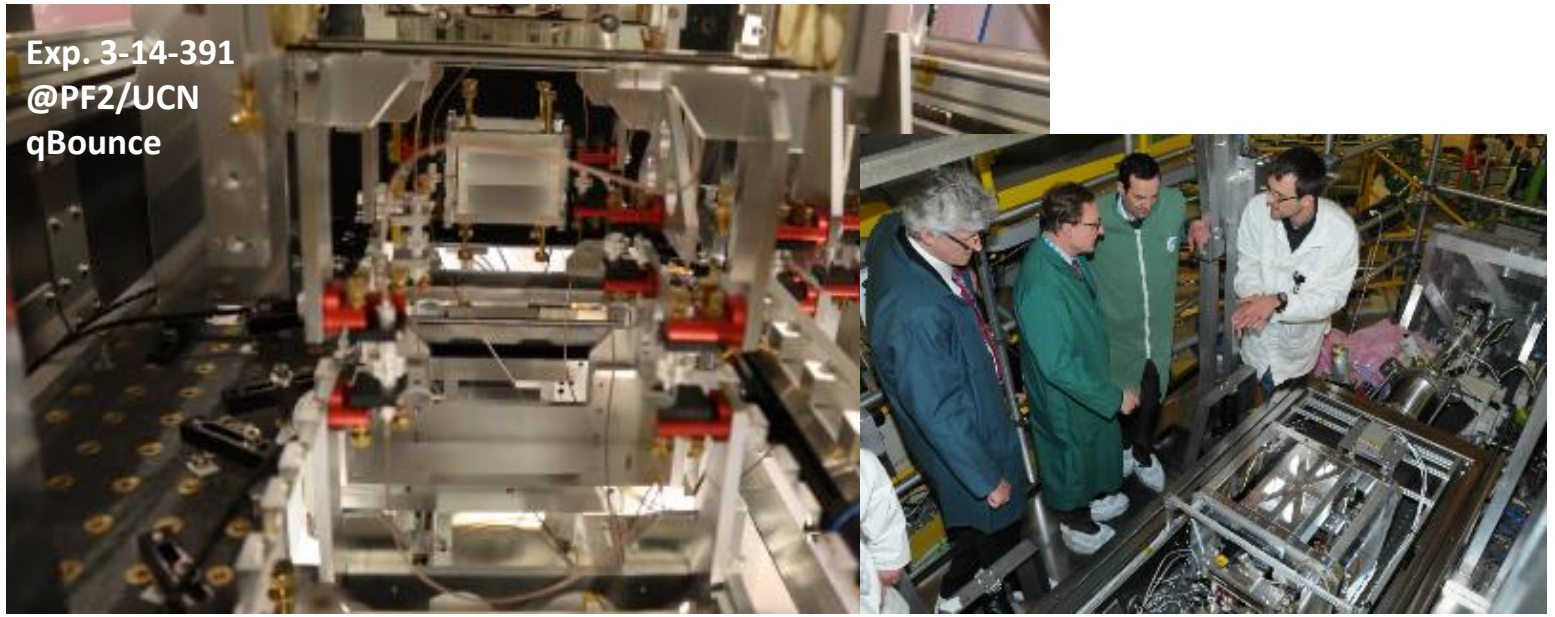

Exp. 3-14-405
@PF2/TES
UCN source development

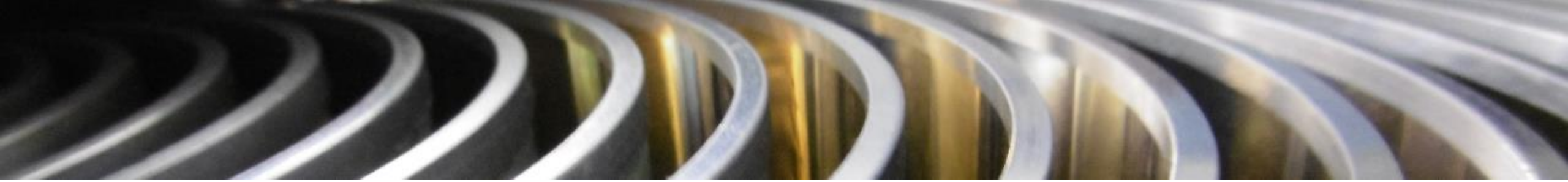
Experiments at PF2

Long-term/large-scale Experiments (LTE)

- Duration: several cycles
- Timing: requires additional backlog
- Equipment: 1 truck of equipment

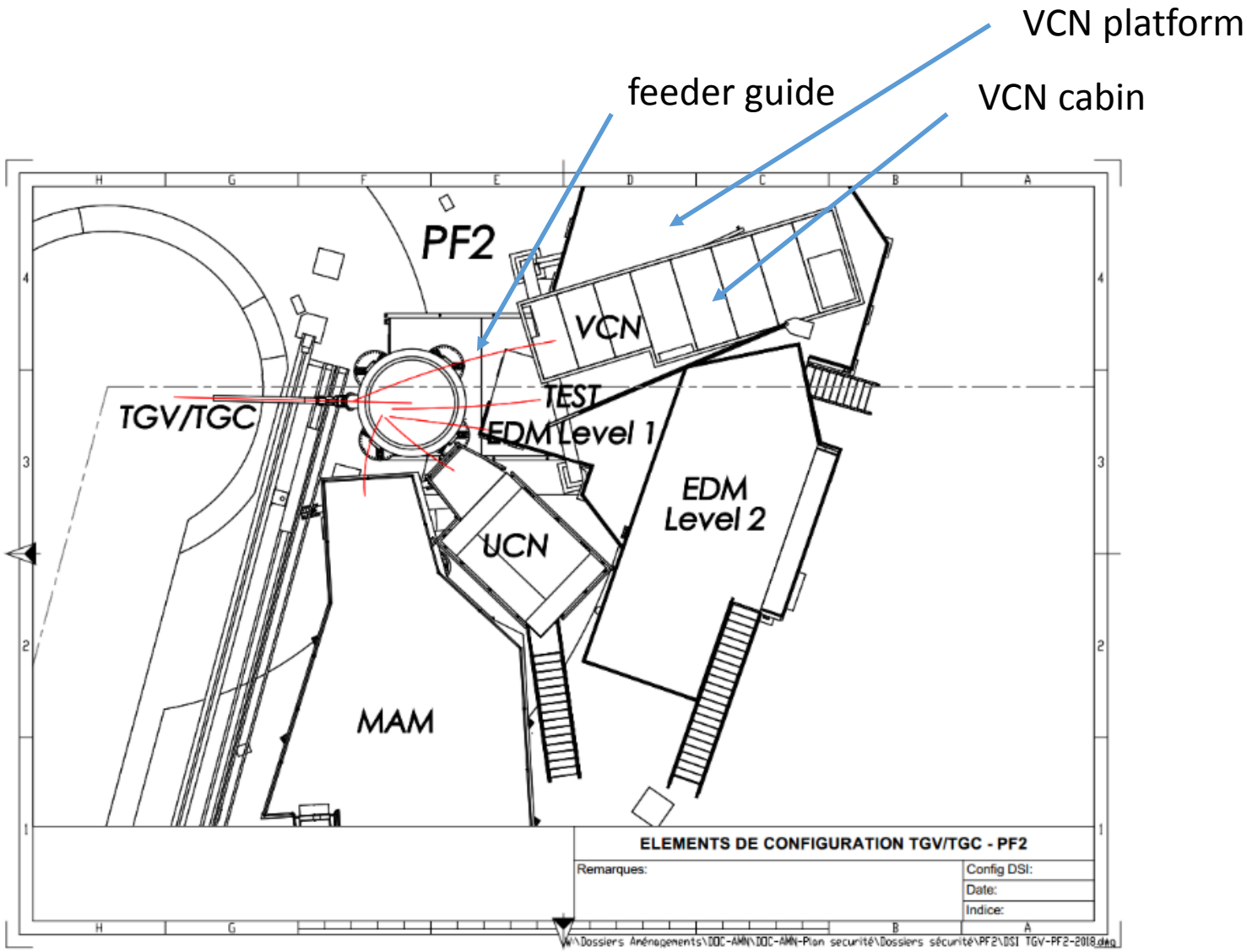






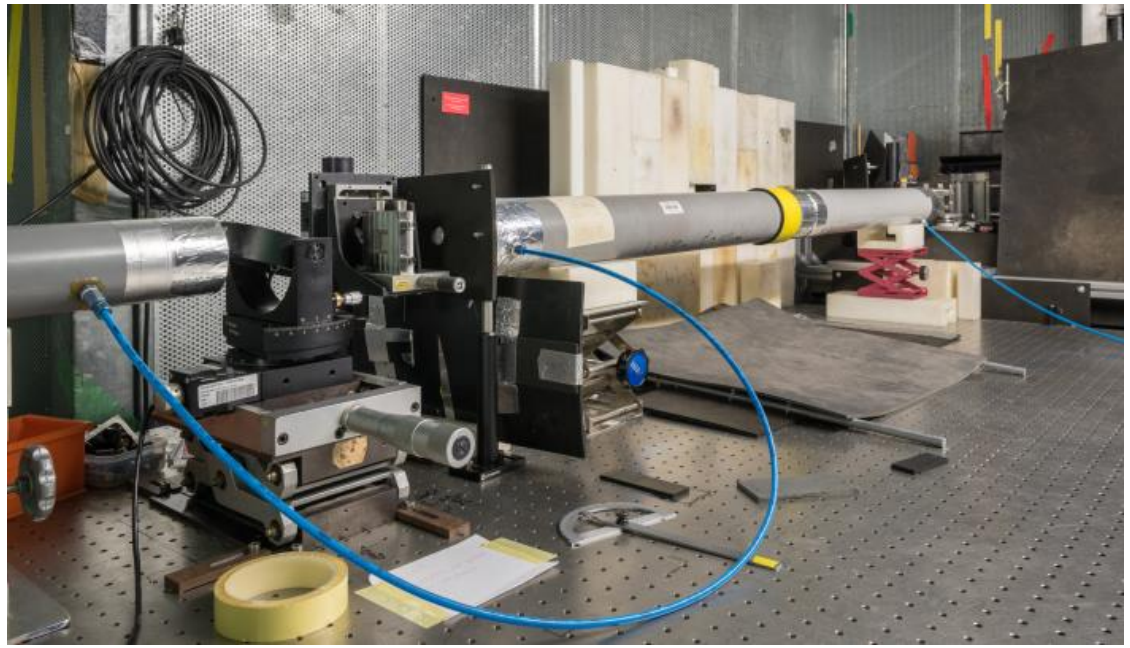
PF2/VCN

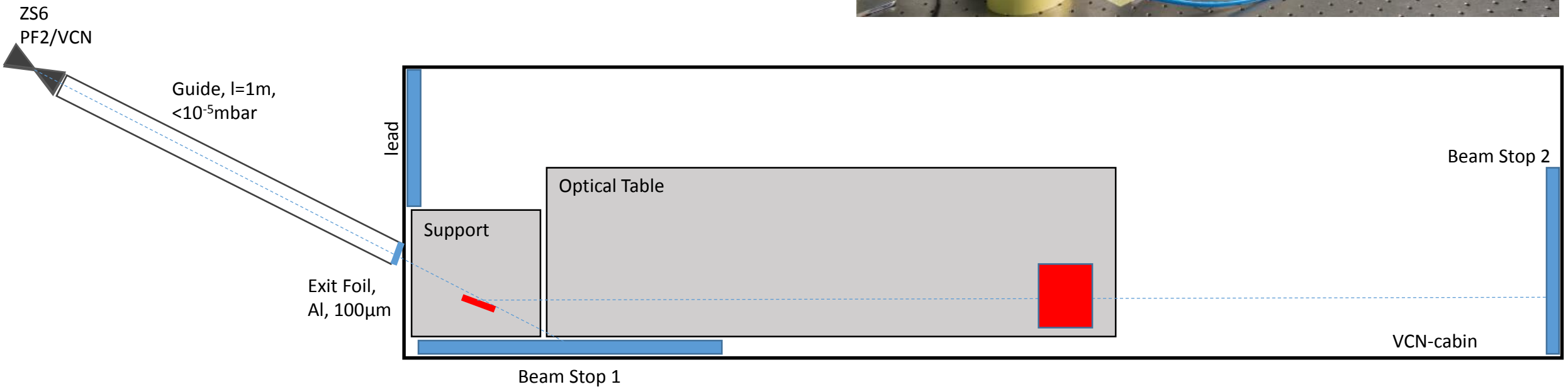
The very cold neutron beam PF2/VCN



Layout: **PF2/VCN**
Configuration: **„empty“**

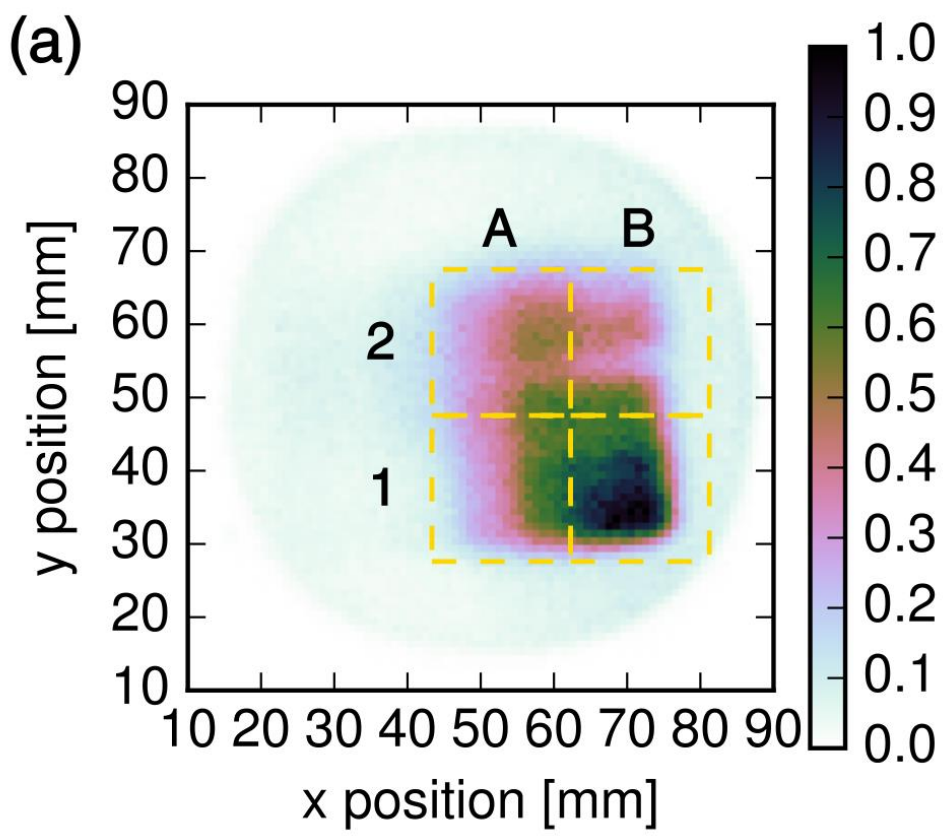
Beam ports
20 - 400 Å
7 cm high and 3.4 cm wide.
v < 40 m/s: the spectrum varies according to the height in the beam
v > 40 m/s: the spectrum is fairly homogeneous
flux at v = 40 m/s (100 Å) : about 10^5 $cm^{-2}s^{-1}(m/s)^{-1}$ (= 0.4 x 10^5 $cm^{-2}s^{-1}Å^{-1}$)

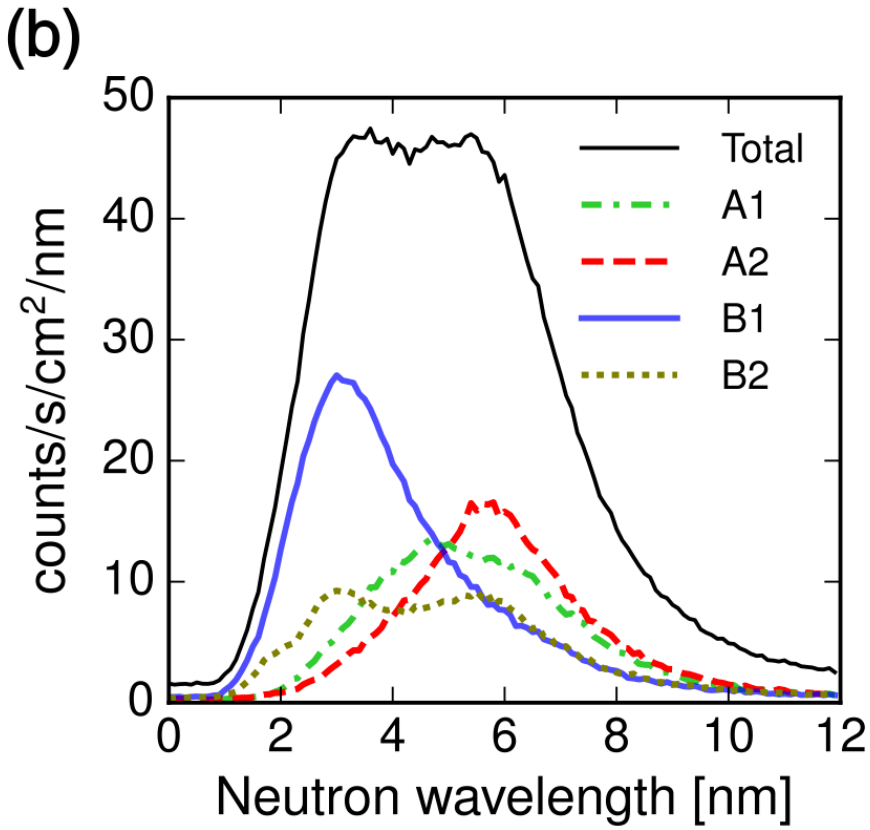




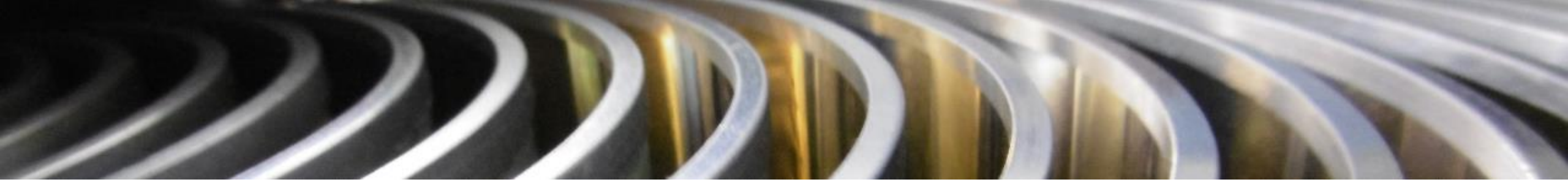
Source Performance

Beam Profile and Wavelength Spectrum





T. Oda et al., NIM A860, 35 (2017).



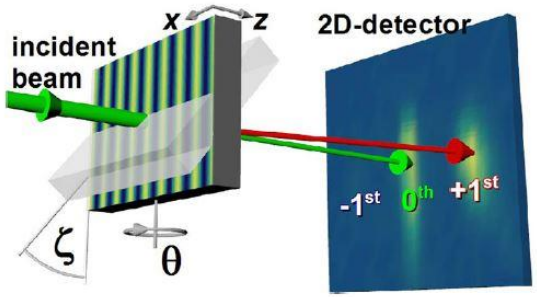
Examples of User Experimements

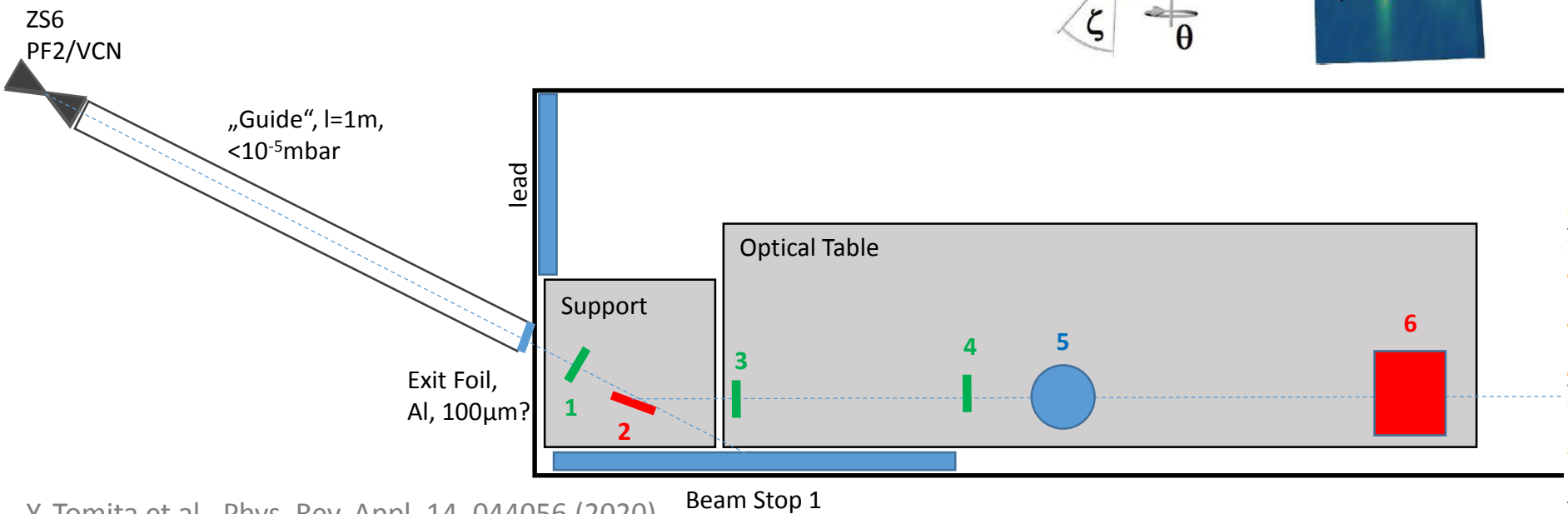
Layout: PF2/VCN
Configuration: Standard VCN optics

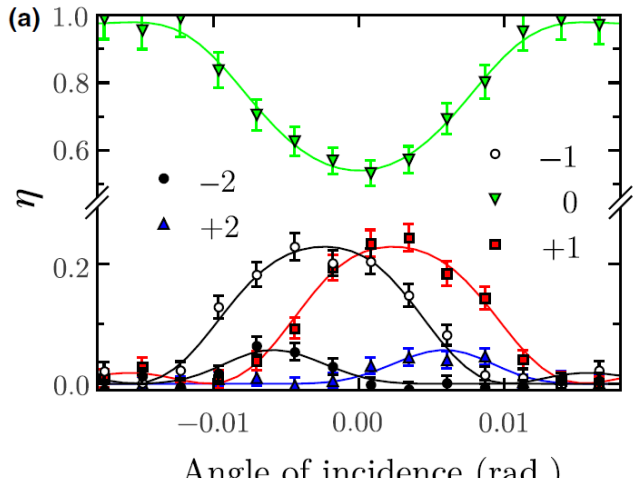
Nanodiamond-dispersed composite holographic gratings and their light and slow-neutron diffraction properties

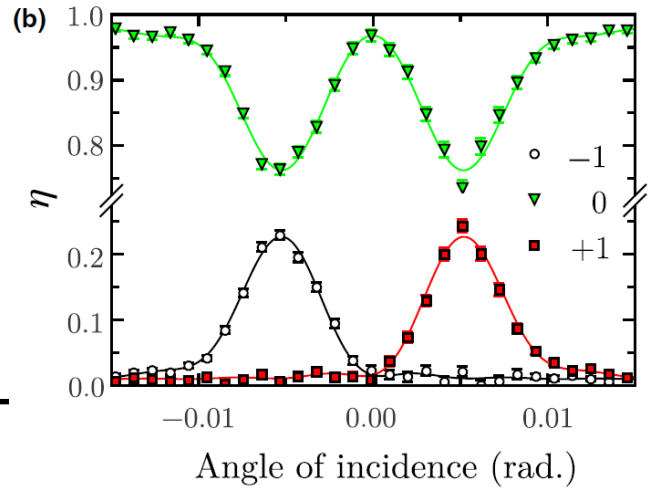
J. Klepp[1], M. Fally[1], C. Pruner[2] et al.
([1] Uni Wien, [2] Uni Salzburg)

- Development of diffraction gratings for long-wavelength neutron optics by using light-sensitive materials combined with holographic techniques









Grating	No. 1 ($\Lambda = 1\ \mu$m)	No. 2 ($\Lambda = 0.5\ \mu$m)
Light diffraction		
d [μm]	25.29 ± 0.02	35.31 ± 0.04
Δn_{sat}	$\approx 4.7 \times 10^{-3}$	$\approx 2.2 \times 10^{-3}$
$a_1 \Delta f$	≈ 0.011	≈ 0.005
Slow-neutron diffraction		
d [μm]	25.0 ± 1.4	33.2 ± 1.4
$\bar{\lambda}_N$ [nm]	4.8 ± 0.3	5.0 ± 0.1
$\Delta n_{sat,N} = 2\lvert n_1 \rvert$ [$\times 10^{-5}$]	1.3 ± 0.1	0.9 ± 0.1
n_2 [$\times 10^{-6}$]	-1.9 ± 0.3	N/A (see text)
$(b_c \rho)_{NP}$ [$\times 10^{-6}$ Å^{-2}]	≈ 3.4	≈ 4.4

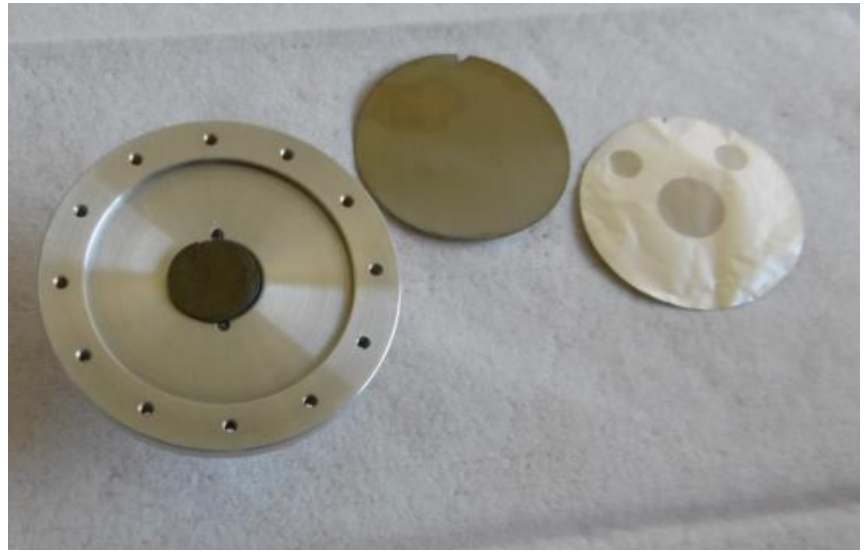
Y. Tomita et al., Phys. Rev. Appl. 14, 044056 (2020)

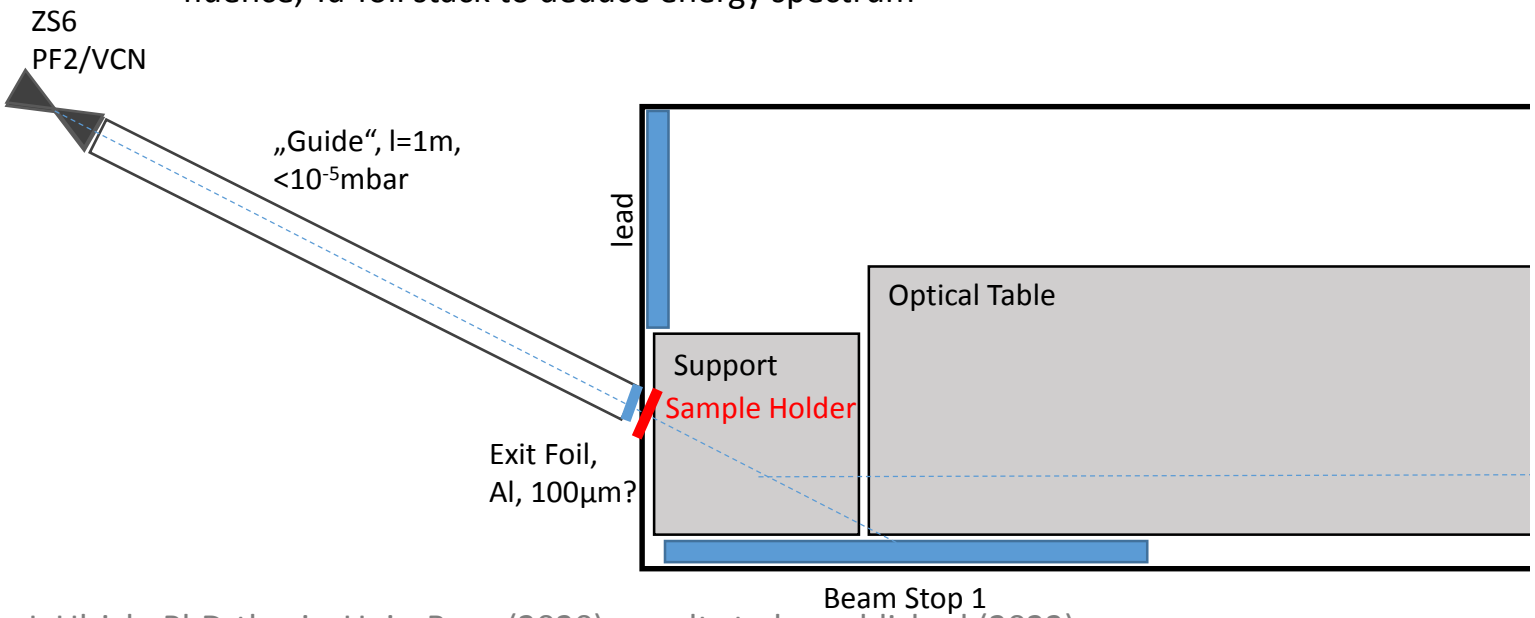
Layout: PF2/VCN
Configuration: Activation

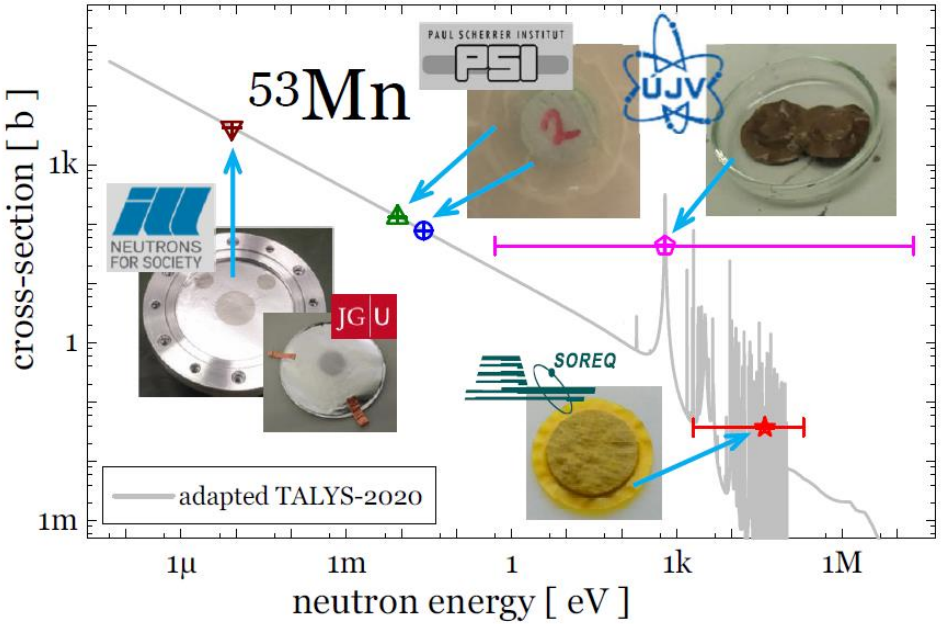
Measurement of the Mn-53 neutron capture cross-section with Very Cold Neutrons (VCN)

Proposers: J. Ulrich, R. Dressler, D. Schumann, B. Lauss
(Paul Scherrer Institut, CH)

- Short-lived cosmogenic radionuclide, produced in explosive stages of stellar life, suspected to be a major radionuclide produced in type-II-supernovae
- Cross section was poorly known before the experiment (2 experiments at thermal energies with differing results by a factor of three)
- 10^{16} Mn-53-ions implanted in 6 micron Alu foil, Co-59-layer for neutron fluence, Ta-foil stack to deduce energy spectrum







J. Ulrich, PhD-thesis, Univ. Bern (2020); results to be published (2022).

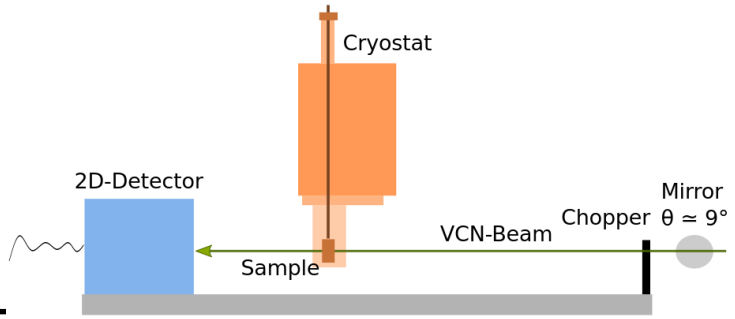
Layout: PF2/VCN
Configuration: Experiments with TOF-option

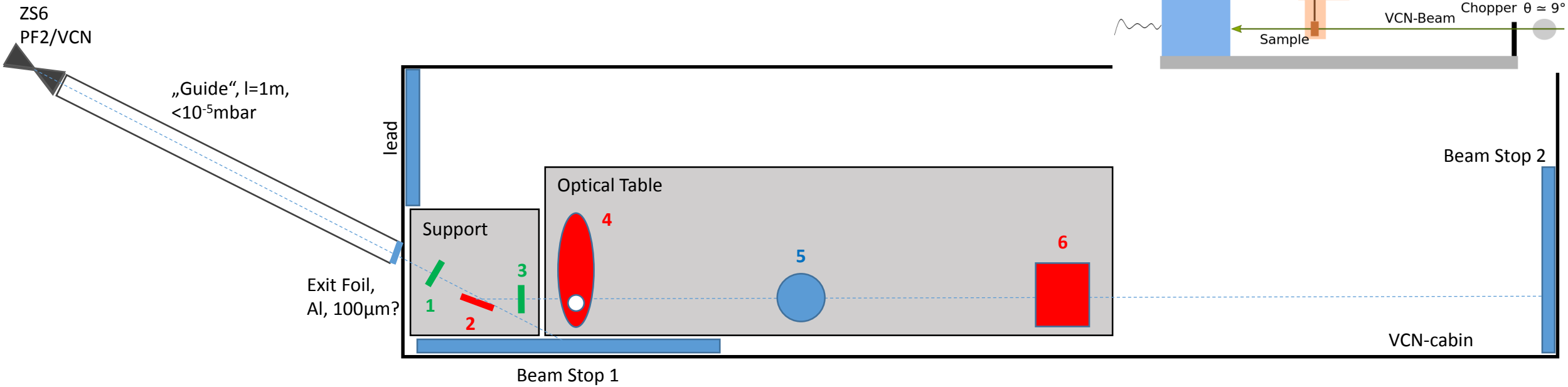
Neutron transmission through clathrate hydrate samples for new very-cold-neutron moderators

O. Zimmer[1], R. Wagner[1], V. Czamler[1], V. Santoro[2]
([1] ILL, [2] ESS)

Experiment performed in Sep/Oct. 2021

- Measurement of total cross section of Tetrahydrofuran clathrate hydrate (TDF-D20) at T=5K.
- Mean free path...

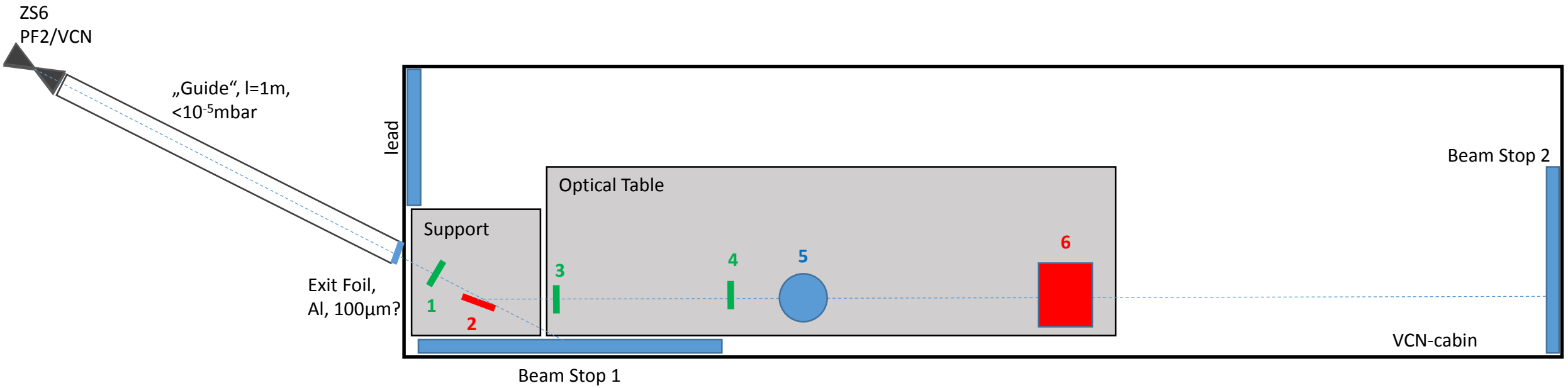


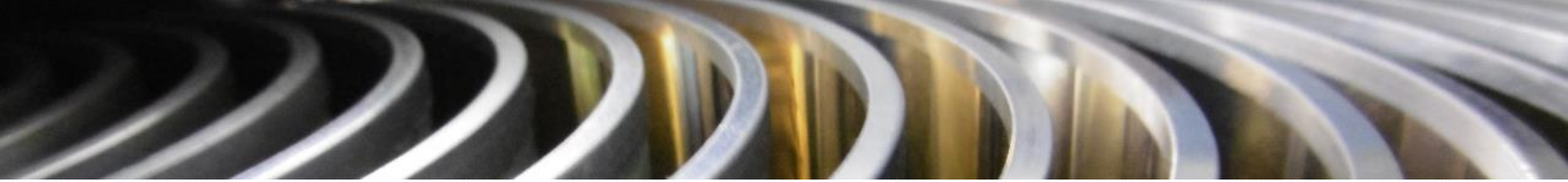


Modernization Program PF2VCNup!

E. Hadden, T. Jenke, SCI (P. Mutti)

- Improve neutron output
- Improve shielding (biological and detector)
- Fully automize all apertures, goniometers and sample holders
- Provide a fully supported option for TOF and velocity-selected measurements
- Instrument control (all axes + detectors) via ILL standards (NOMAD)





Thank you very much for your attention!