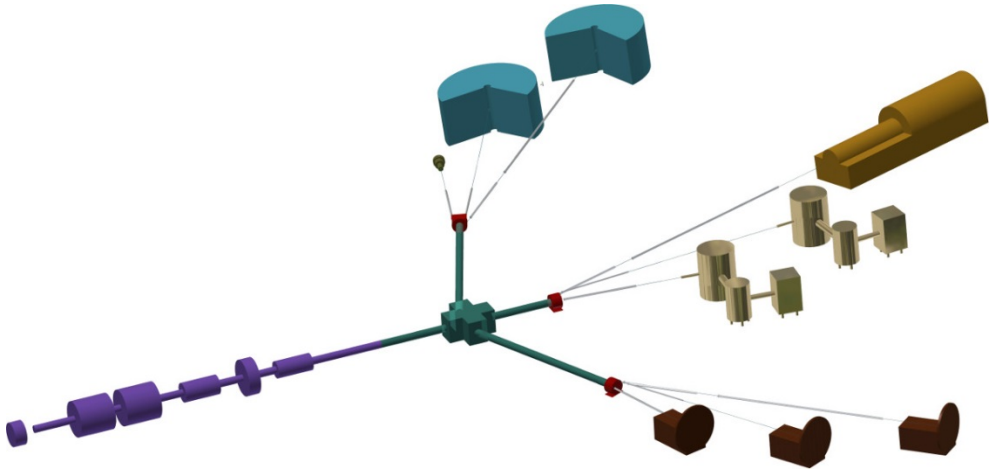


HBS moderator development

Thermal and cold moderator for the High Brilliance neutron Source Jülich

Tobias Cronert[1] , Jan Philipp Dabruck[2] , Paul-Emmanuel Doege[2] , Yannik Beßler[4] , Ulrich Rücker[1] , Carsten Lange[3] , Michael Butzek[4] , Wolfgang Hansen[3] , Rahim Nabbi[2] and Thomas Brückel[1]

[1] JCNS - Forschungszentrum Jülich GmbH, Jülich, Germany
[2] NET - RWTH Aachen University, Germany
[3] TU Dresden, Germany
[4] ZEA 1 - Forschungszentrum Jülich GmbH, Jülich, Germany

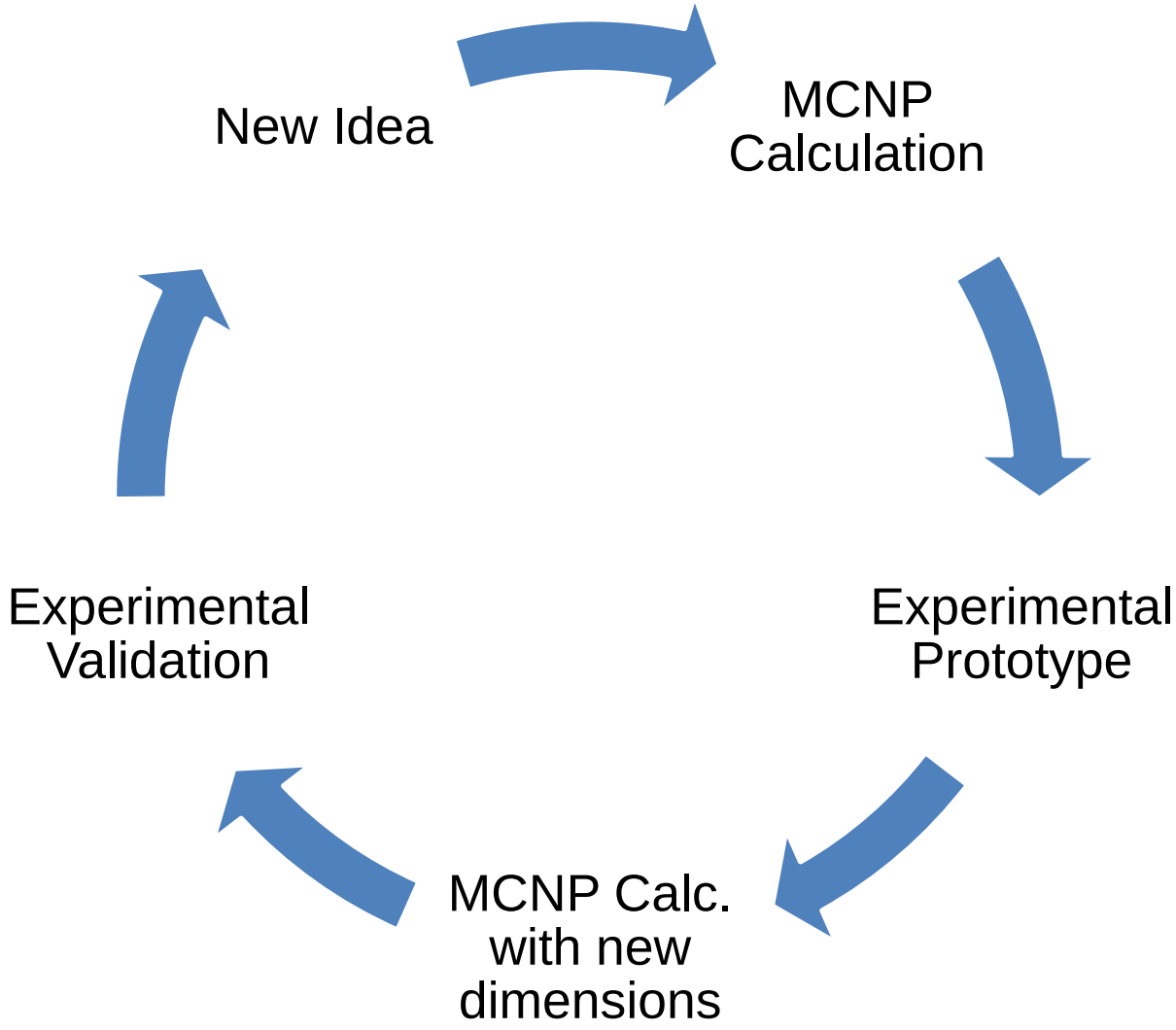
Outline

- Motivation
  - choice for source
- Working procedure
- Moderator setup
  - Shape
  - Material
- Beam extraction
  - Thermal & cold finger
- MCNP Validation at AKR – 2
- First experiment at TREFF
- Outlook

Motivation

- Low energy, below spallation level
- Spallation produces 1000 times more neutrons per incident proton, than 9Be(d,n) or 9Be(p,n) but neutrons not usable to a high degree
- Lower source flux, but more brilliance at sample
- All components optimized to each other and the energy spectrum used

Working procedure

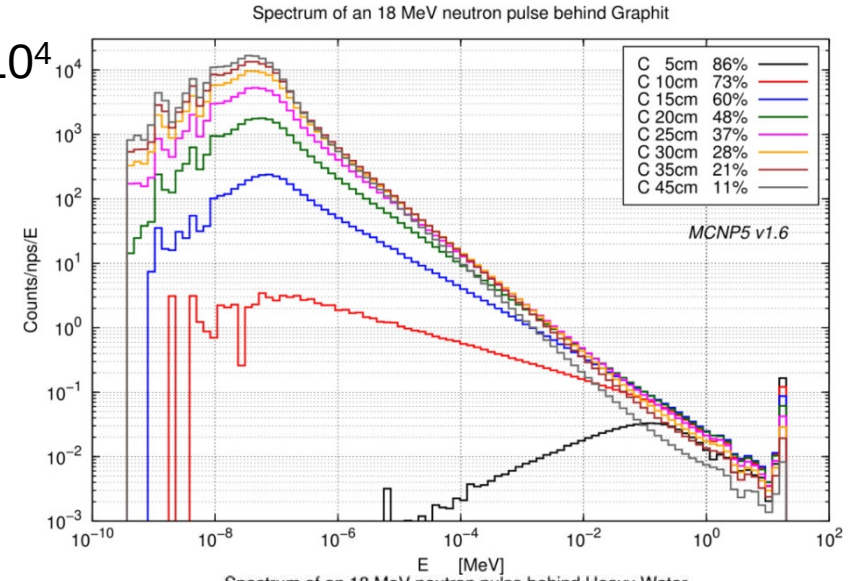


Moderator material

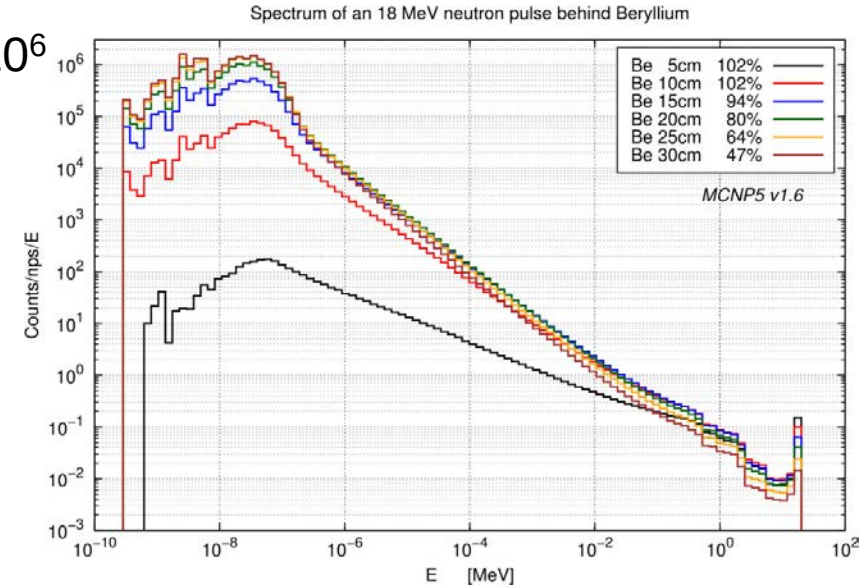
Material:

- Beryllium
- D_2O
- Graphite

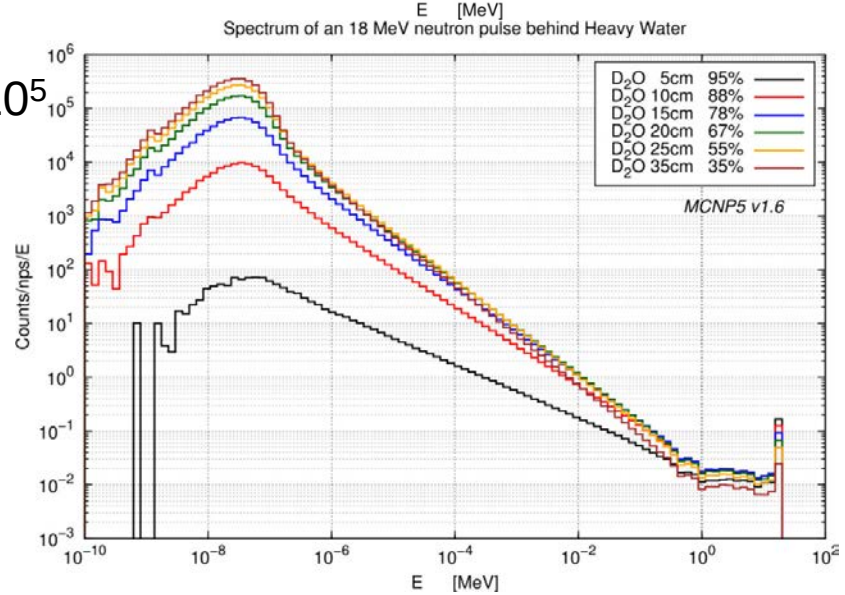
10^4



10^6

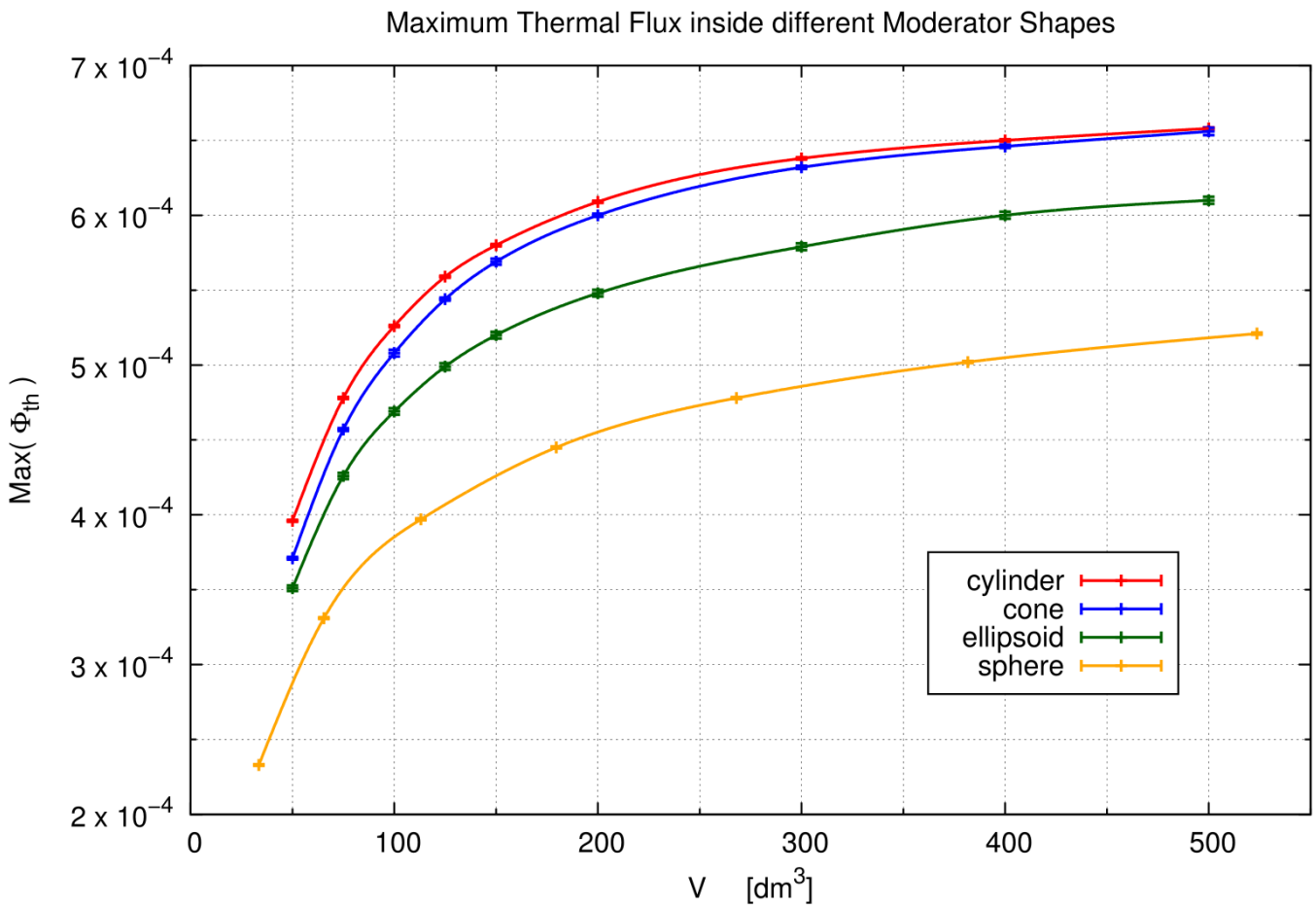


10^5



Moderator shape

Shape
- Cube
- Sphere
- Cone
- Cylinder



AKR – 2 reactor TU-Dresden

- quantitative validation of MCNPX calculations
- fission source with 2 W nominal power
- different cold moderators
- online ortho/para measurement via Raman-spectroscopy or heat capacity
- different geometries

Radial „beamline“ Position 2

- Radial beamline looks directly at the reactor core

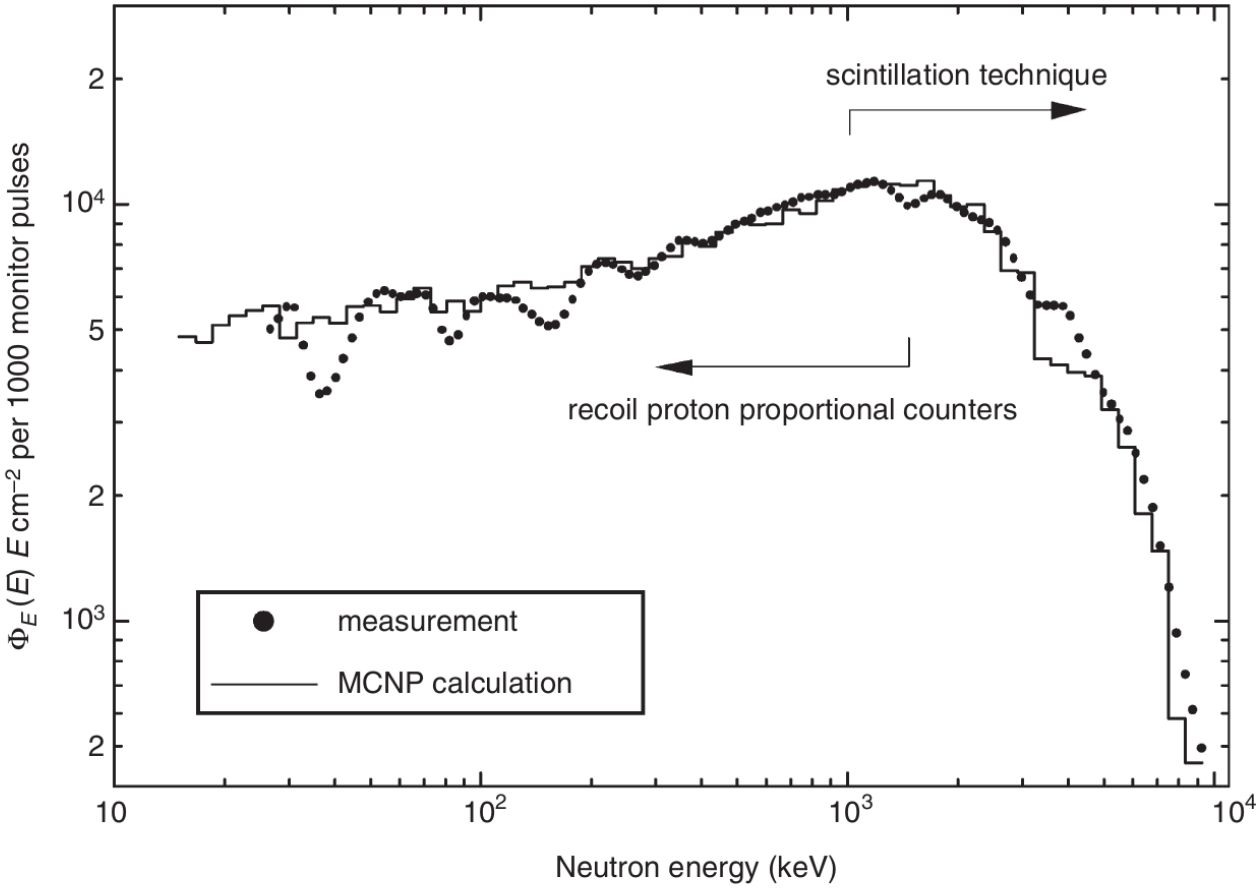
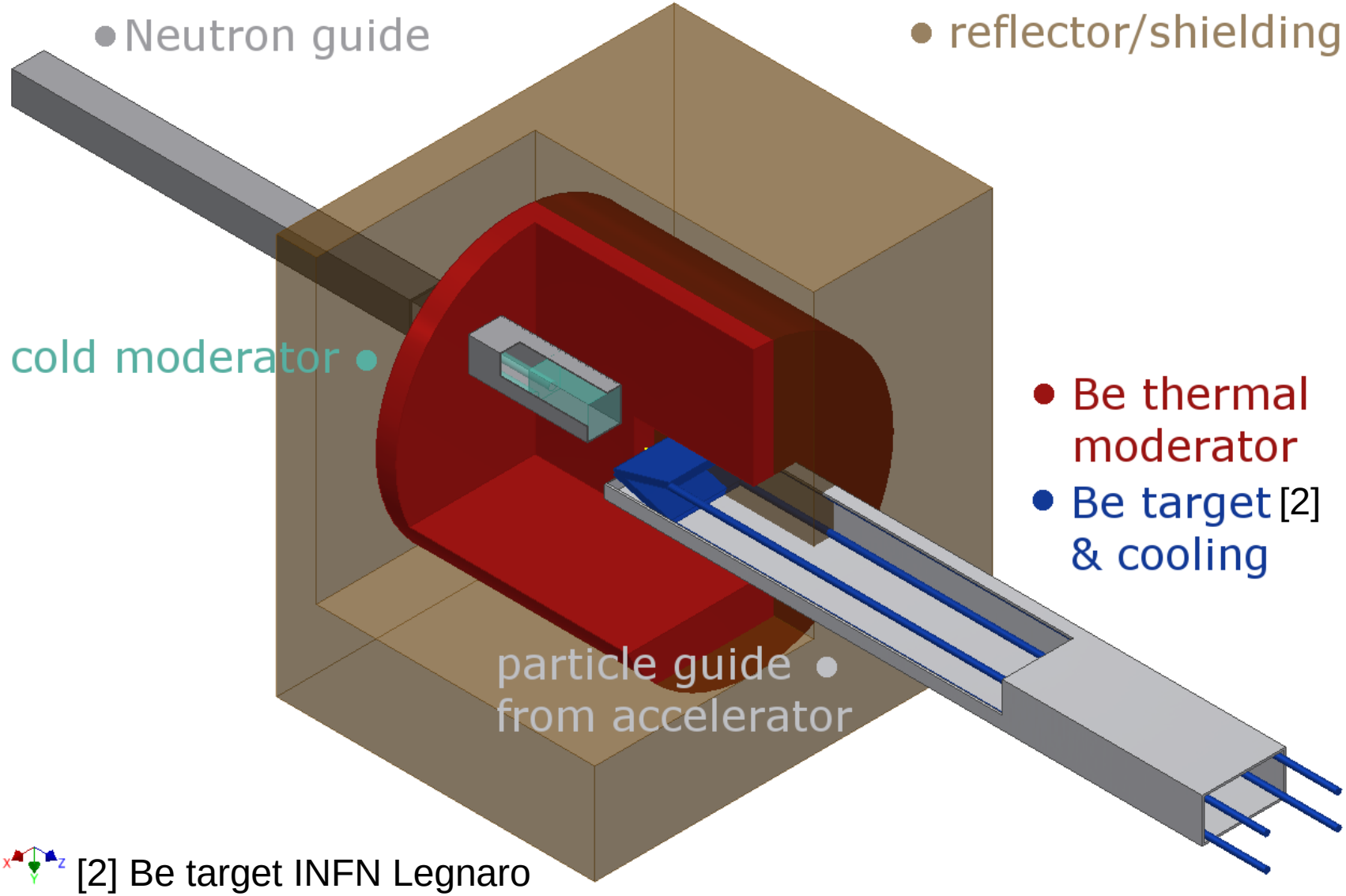


Figure 4.20. Measurement of the neutron spectrum in an experimental irradiation channel of a low-power research reactor by means of recoil proton techniques and comparison with MCNP[51] calculations[52].

1

[1] NEUTRON SPECTROMETRY IN MIXED FIELDS PROPORTIONAL COUNTER SPECTROMETERS
H. Tagziria* and W. Hansen National Physical Laboratory (NPL) Teddington, Middlesex TW11 0LW, UK
Technische Universität Dresden, Mommsenstrasse 13 D-01062 Dresden, Germany

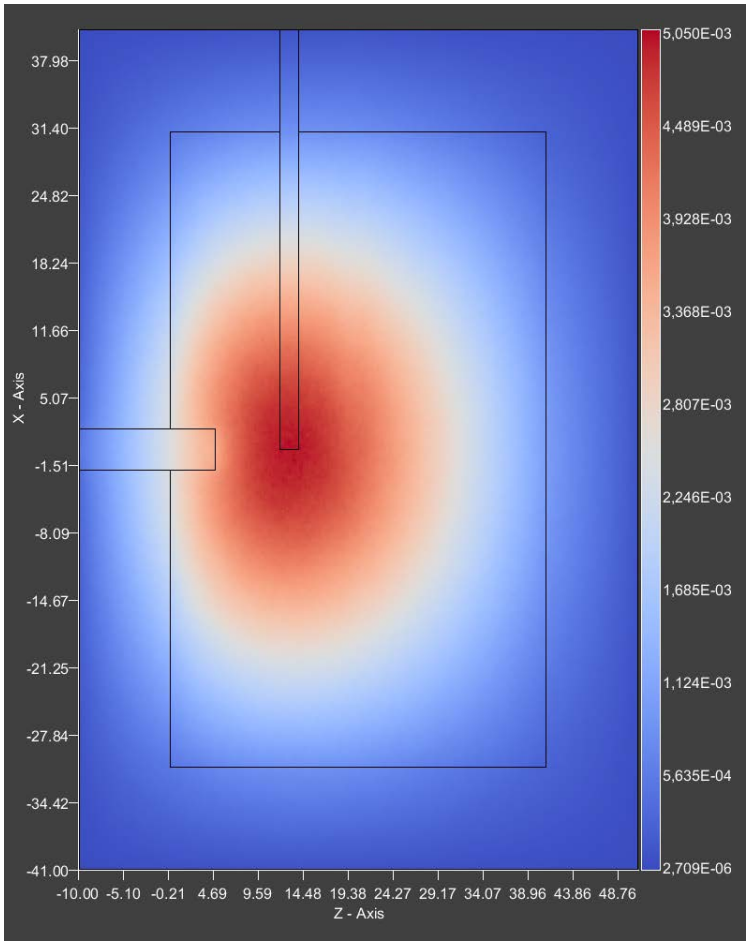
Neutron extraction

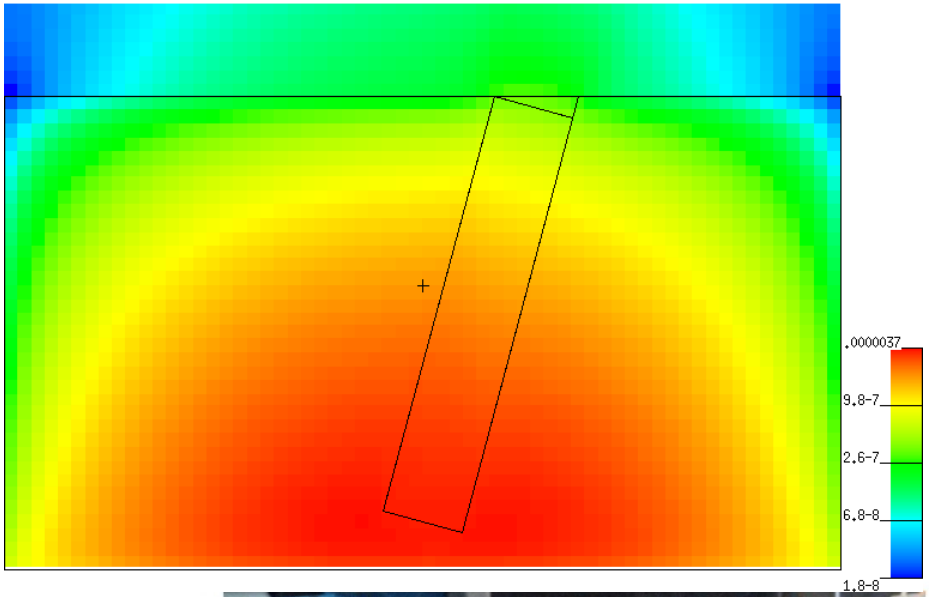


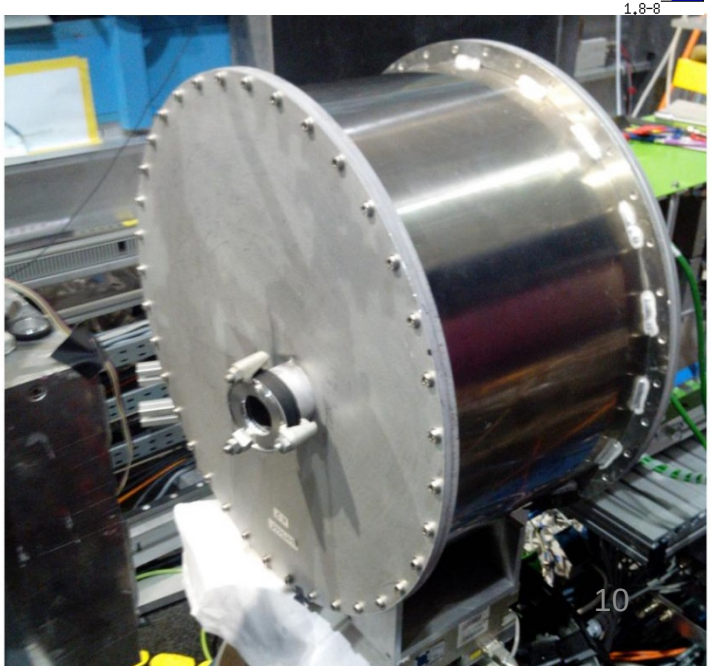
[2] Be target INFN Legnaro

J. Esposito, P. Colautti, S. Fabrisiev, A. Gervash, R. Giniyatulin, V.N. Lomasov, A. Makhankov, I. Mazul, A. Pisent, A. Pokrovsky, M. Rumyantsev, V. Tanchuk, L. Tecchio INFN, STC, SEI, SRIIAR

Neutron extraction

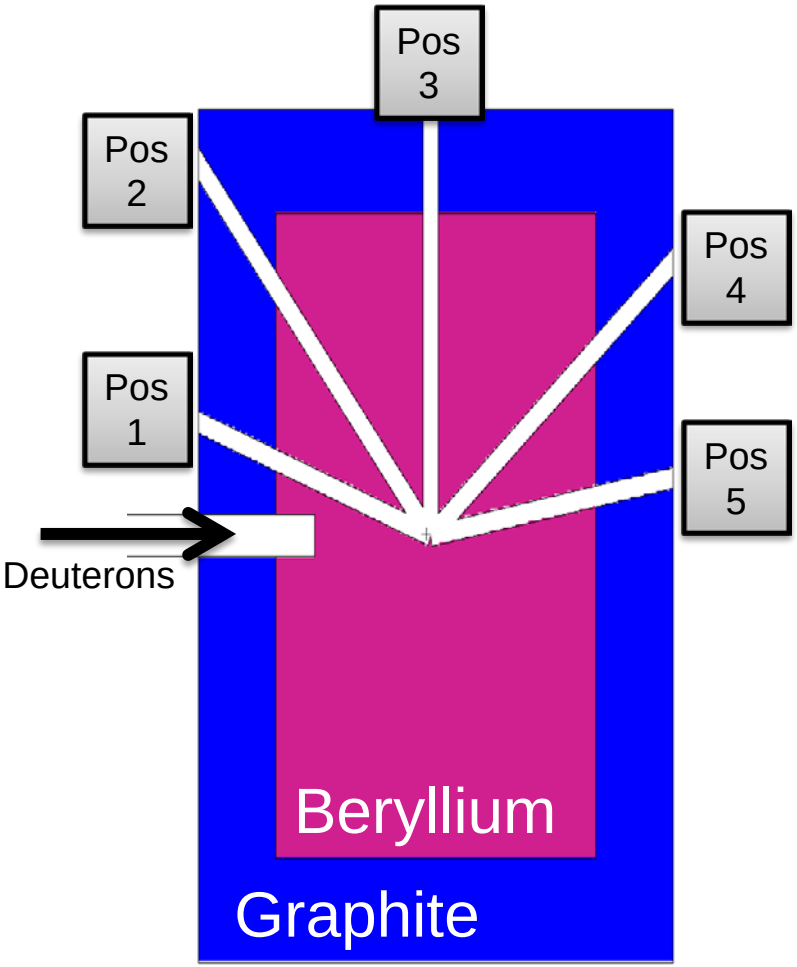


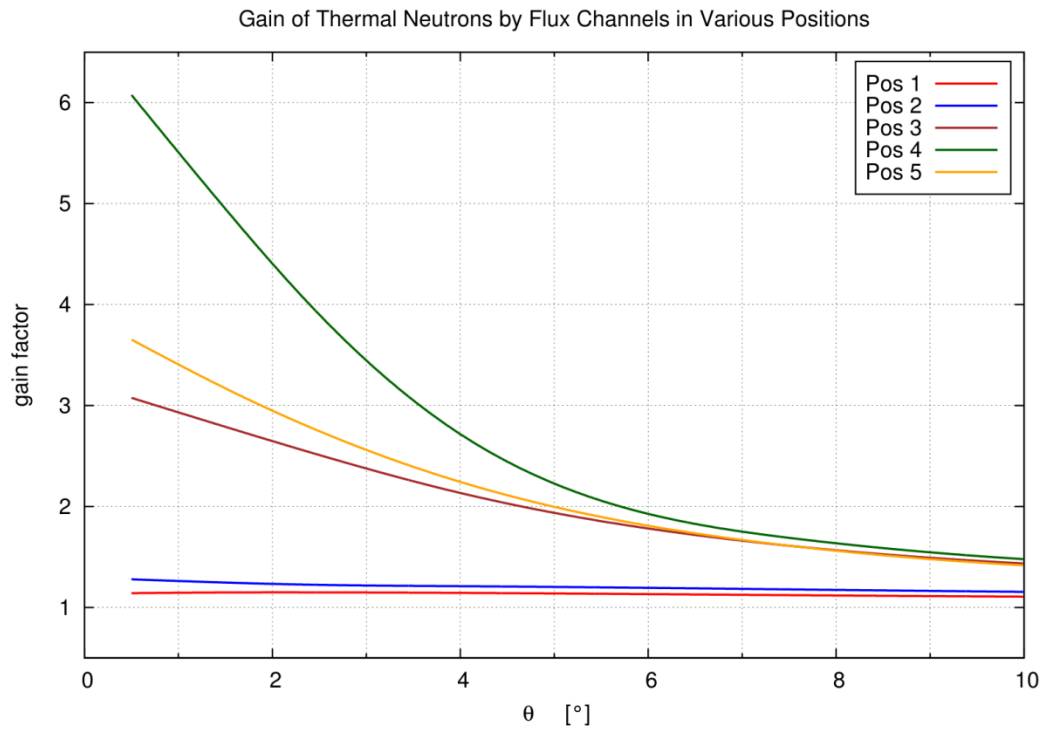




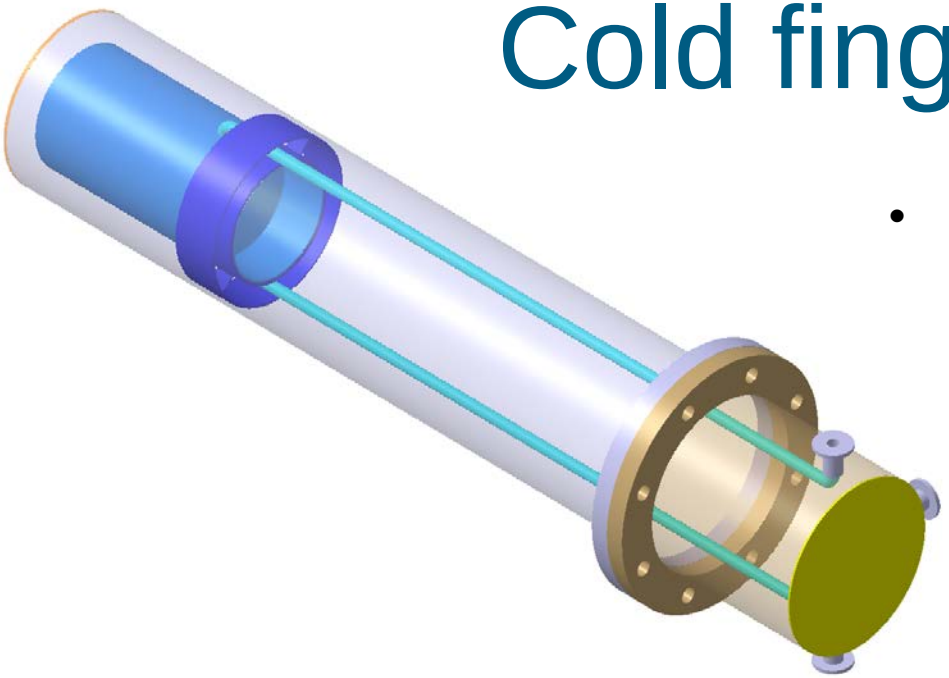
- Neutron extraction from thermal flux maximum

Performance gain

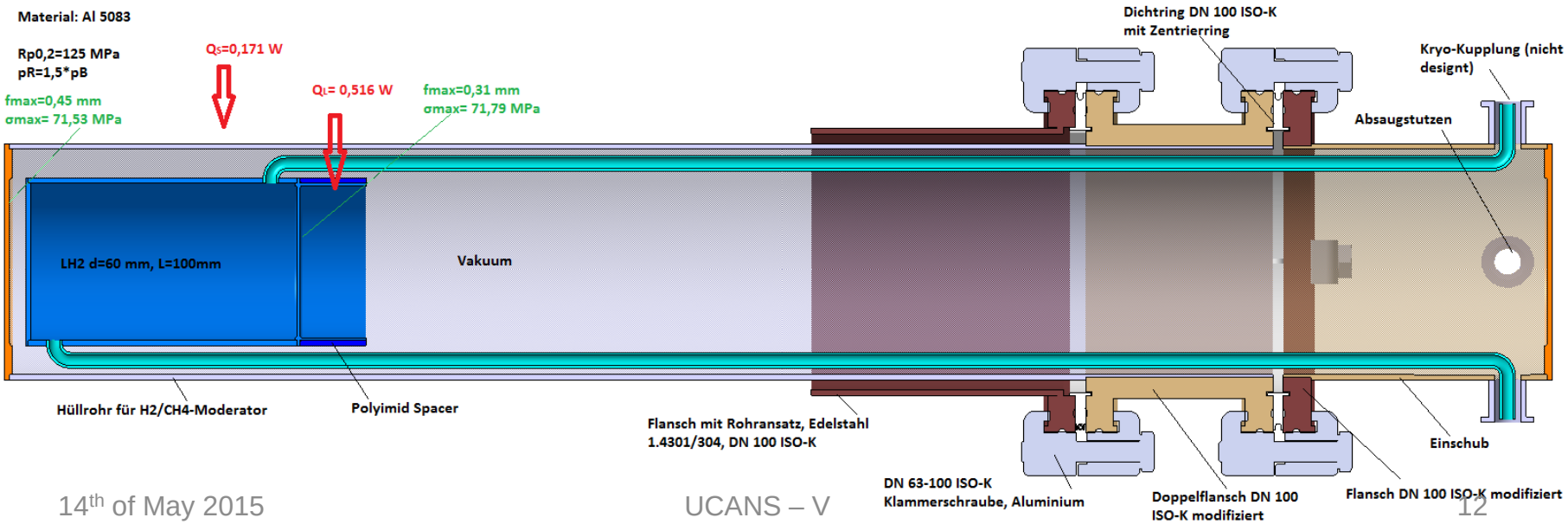




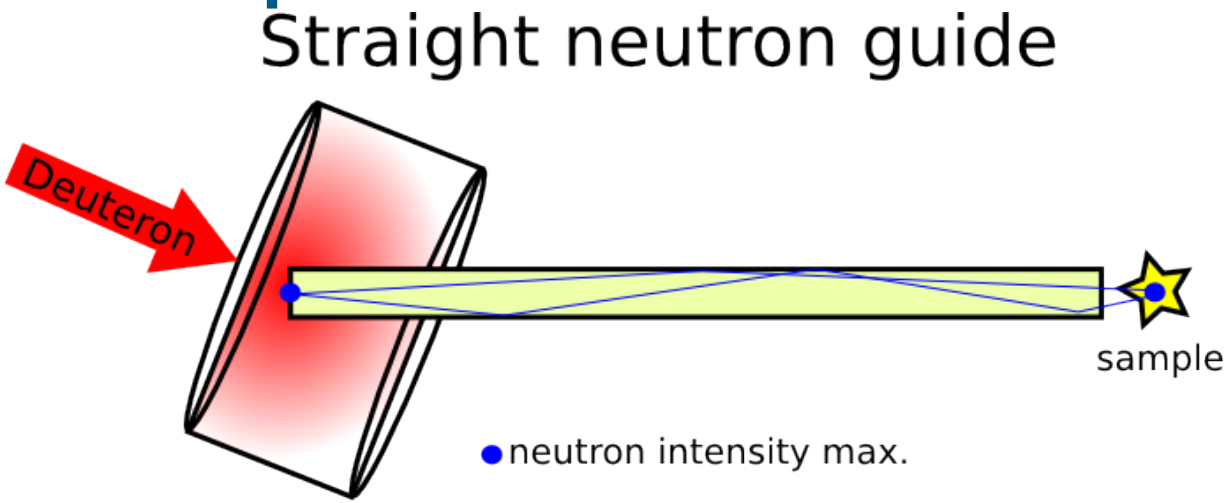
Cold finger



- Cold moderator in thermal neutron maximum (e.g. liquid para H_2)
  - mean free path $\lambda_{th} \approx 1$ cm and $\lambda_{cd} \approx 10$ cm
  - optimum shape: tube with $R = \lambda_{th}$ and $L = \lambda_{cd}$
  - cold neutrons leave with just as much collisions as needed

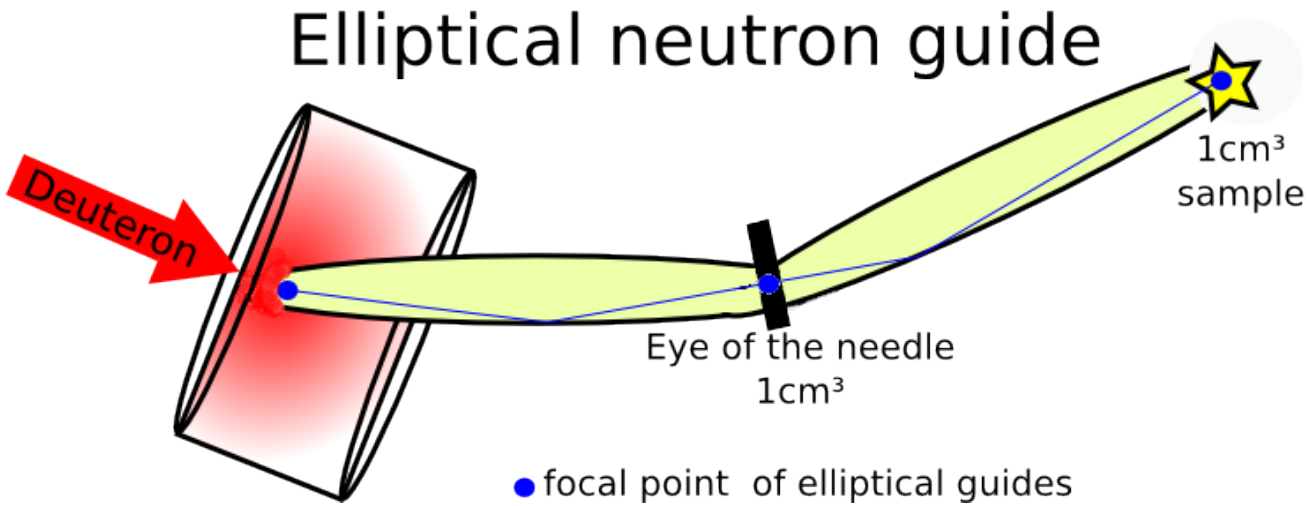


Optimized for small samples

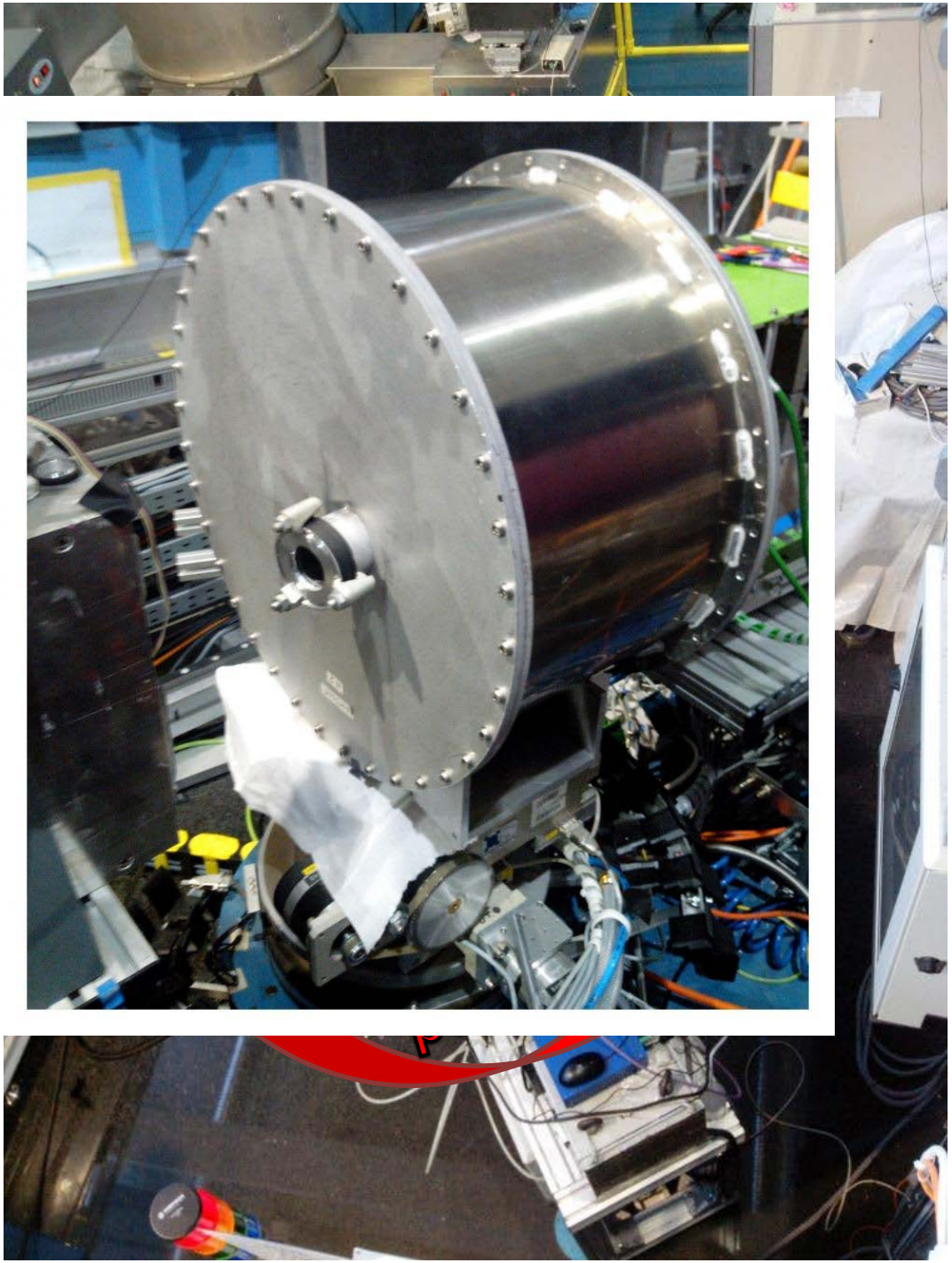


Neutron guides

- Elliptical mirrors with exponentially distributed coating gain a factor of 30[1] in intensity, compared to straight neutron guides
- Eye of the needle
- Optimized for collimation

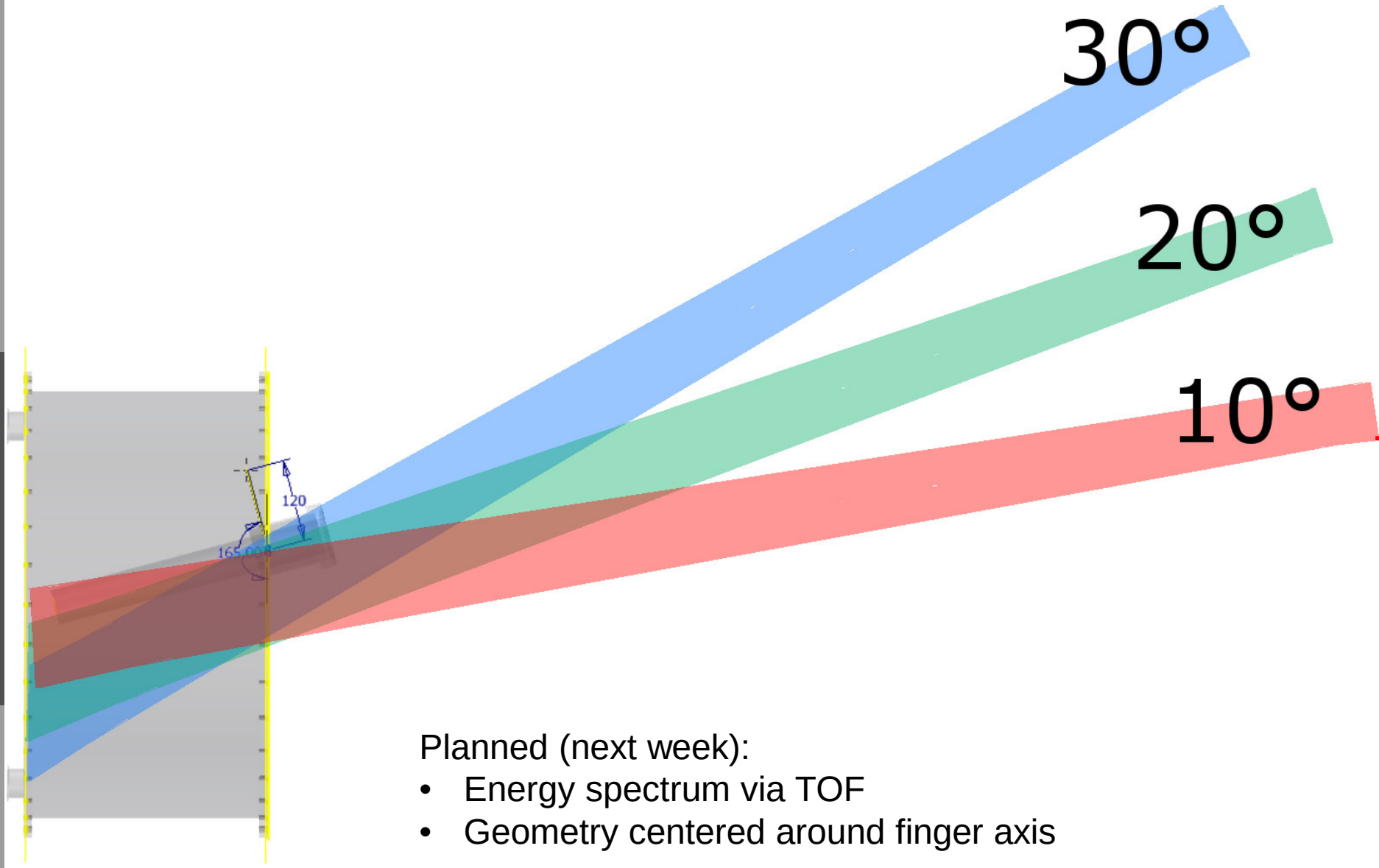


[1] Powerful and Cost-Effective Elliptical Neutron Guide Designs for the ESSKaspar H. Klenø1,5, Kim Lefmann1, Peter Willendrup2, Peter Böni3and Emmanuel Farhi41Nano-Science Center, Niels Bohr Institute, University of Copenhagen,2Risø, Technical University of Denmark,3Technische Universität München4Institut Laue-Langevin5ESS-Scandinavia, University of Lund



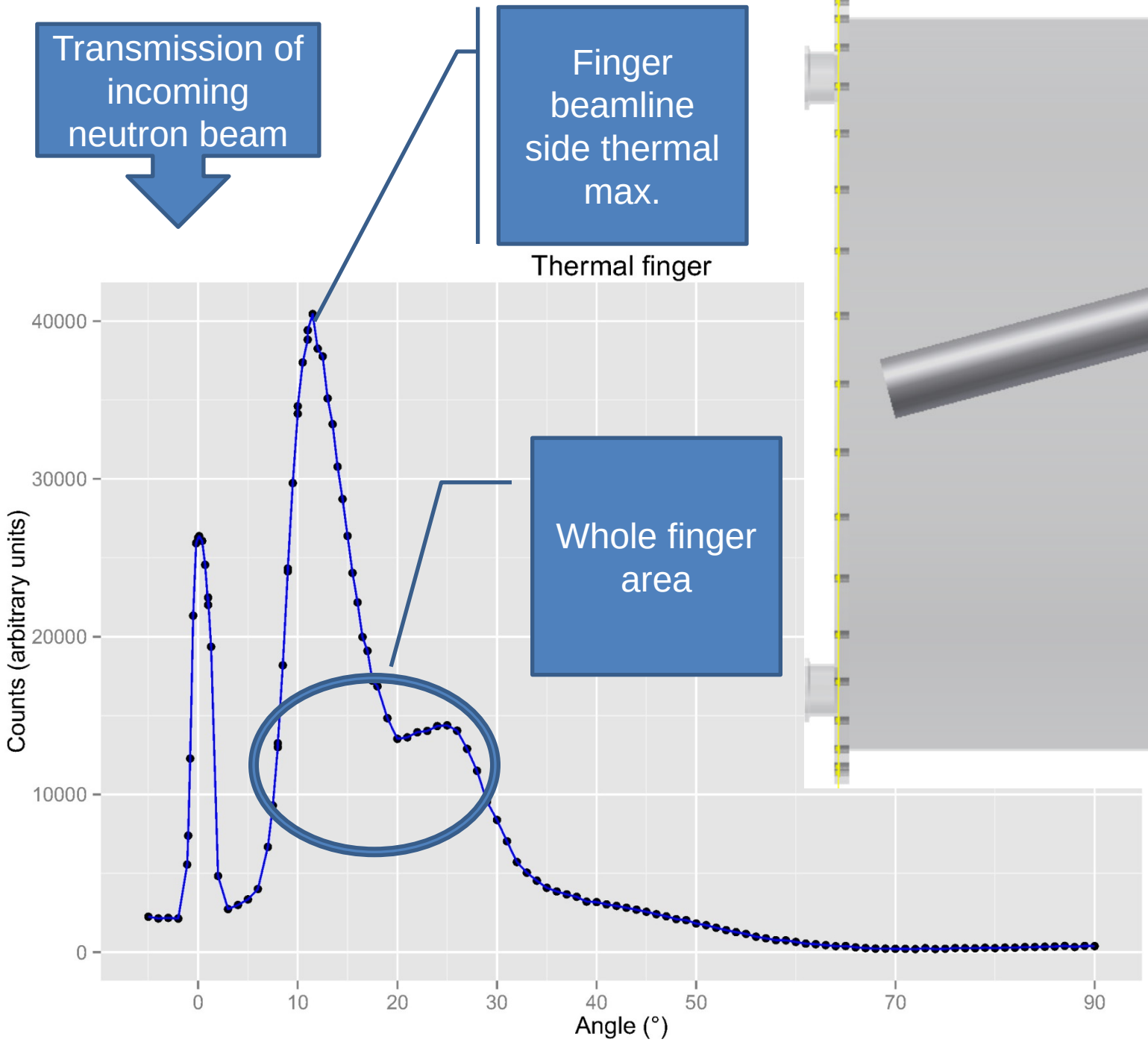
TREFF at MLZ
Research reactor FRM 2

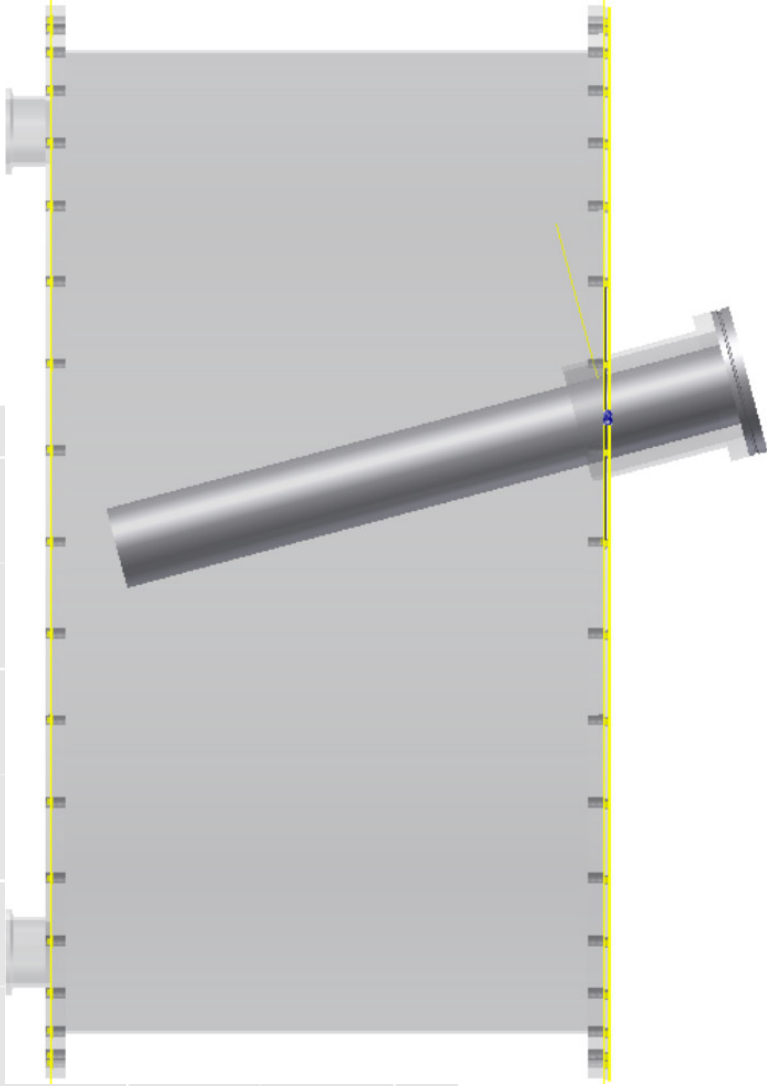
Cold beamline λ = 4.75 Å
Highly collimated



Planned (next week):

- Energy spectrum via TOF
- Geometry centered around finger axis





Outlook

- MCNP-Validation AKR – 2 Dresden
- 2016: Accelerator setup IPHI at CEA Saclay
- HBS prototype

Special thanks to all collaborators and collegues

Thank you for your attention!

MCNPx simulations (type of projectile and energies)

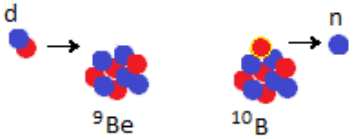
Nuclear Process producing Neutrons	Example	Neutron Yield	Heat Release [MeV/n]
D-T in solid target	*400keV D on T*	*4 n/D*	*10.000*
Nuclear photo effect from Bremsstrahlung	100MeV on U238	5 n/	2000
9Be(d,n)	*15MeV D on Be*	*1.5 n/D*	*1000*
9Be(p,n)	11MeV P on Be	0,5 n/P	2000
Nuclear fission	*fission of U235*	*1n/fission*	*180*
Spallation	800MeV P (U238 or Pb)	27 n/P (17 n/P)	55 (30)

9Be(d,n) 15MeV 1,5 1000

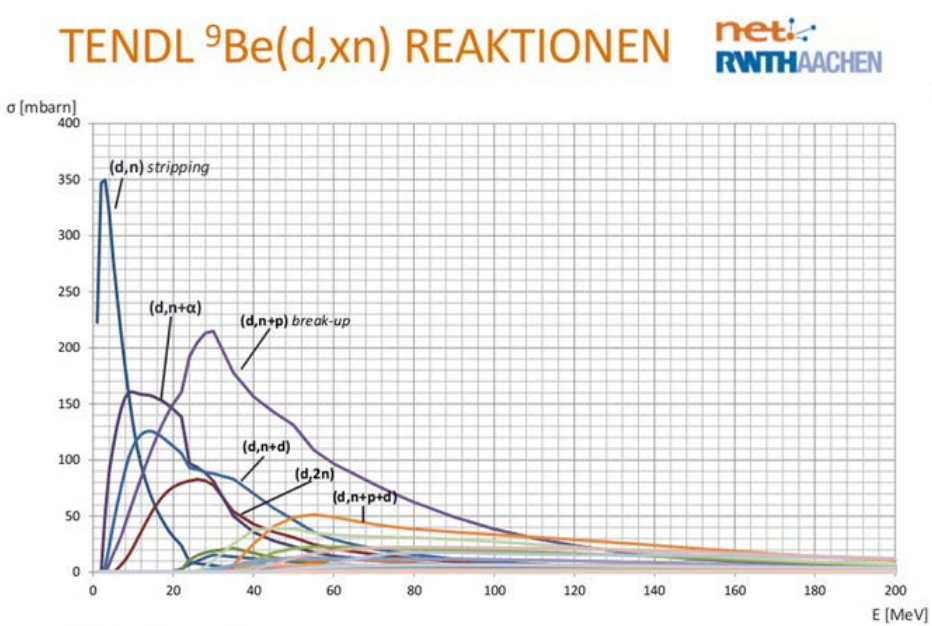
D on Be n/D

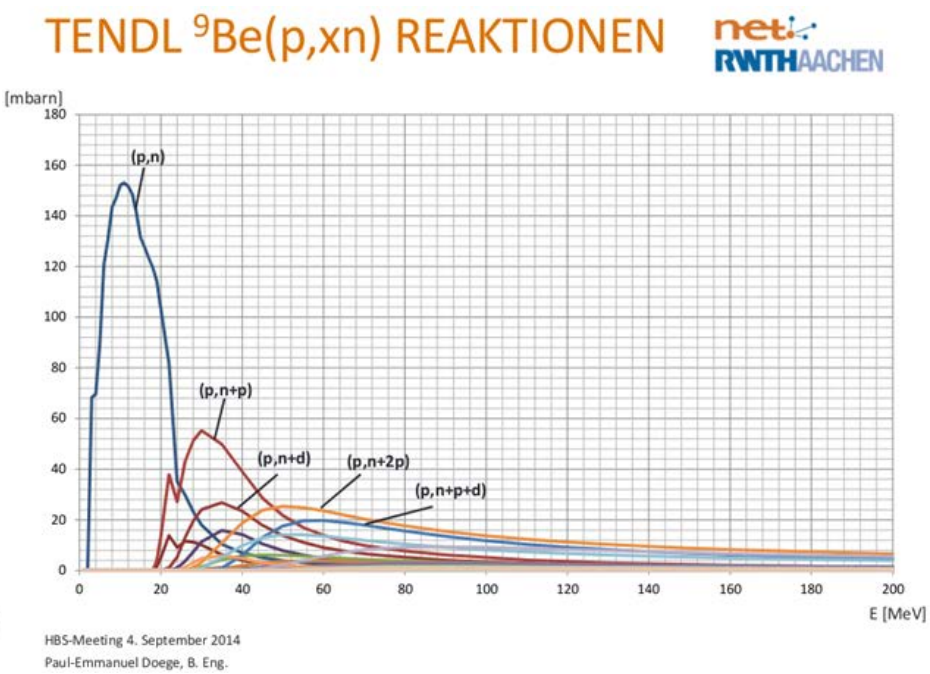
9Be(p,n) 11MeV P 0,5 n/P 2000

on Be

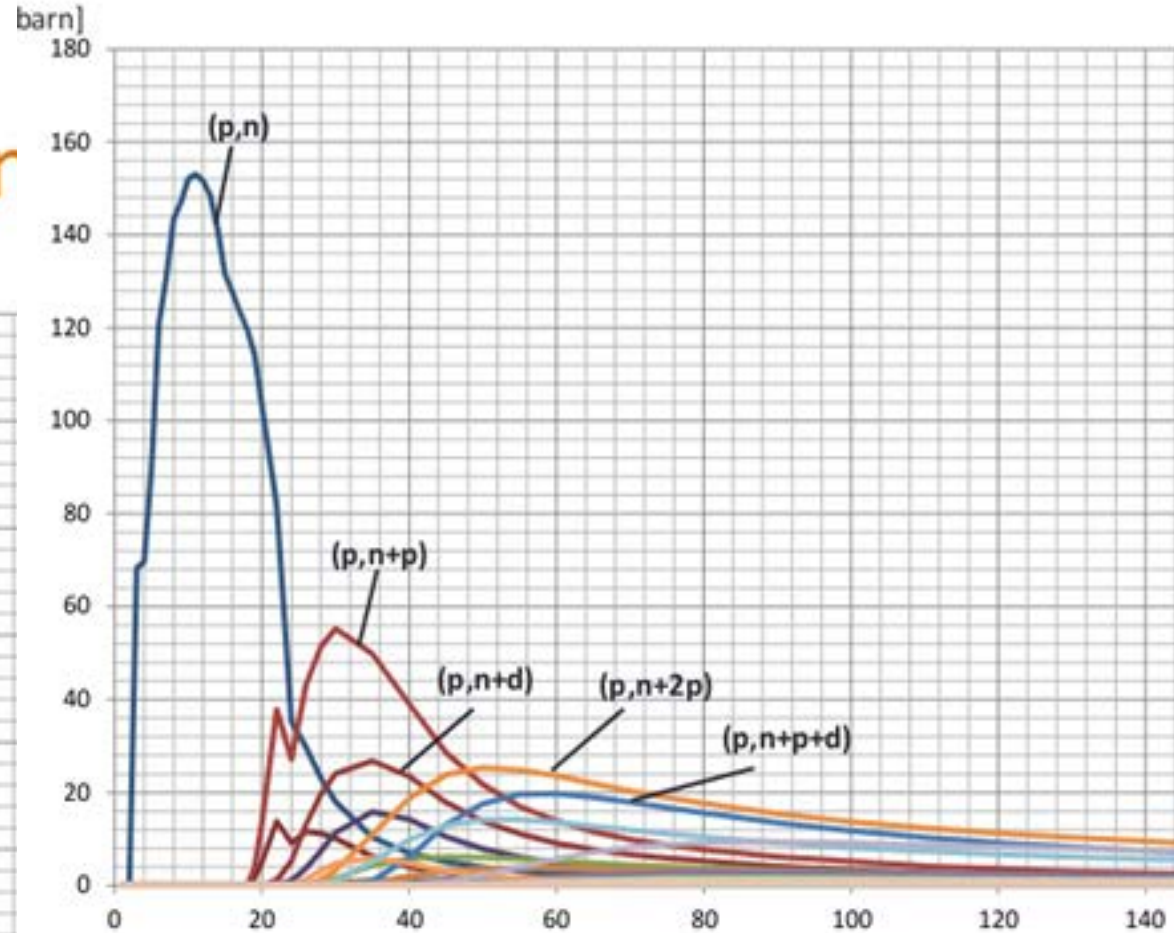


- Deuteron projectile provides „stripping“ and (d,n+p) reaction
- Different reactions at different energies, optimized for accelerator + target setup

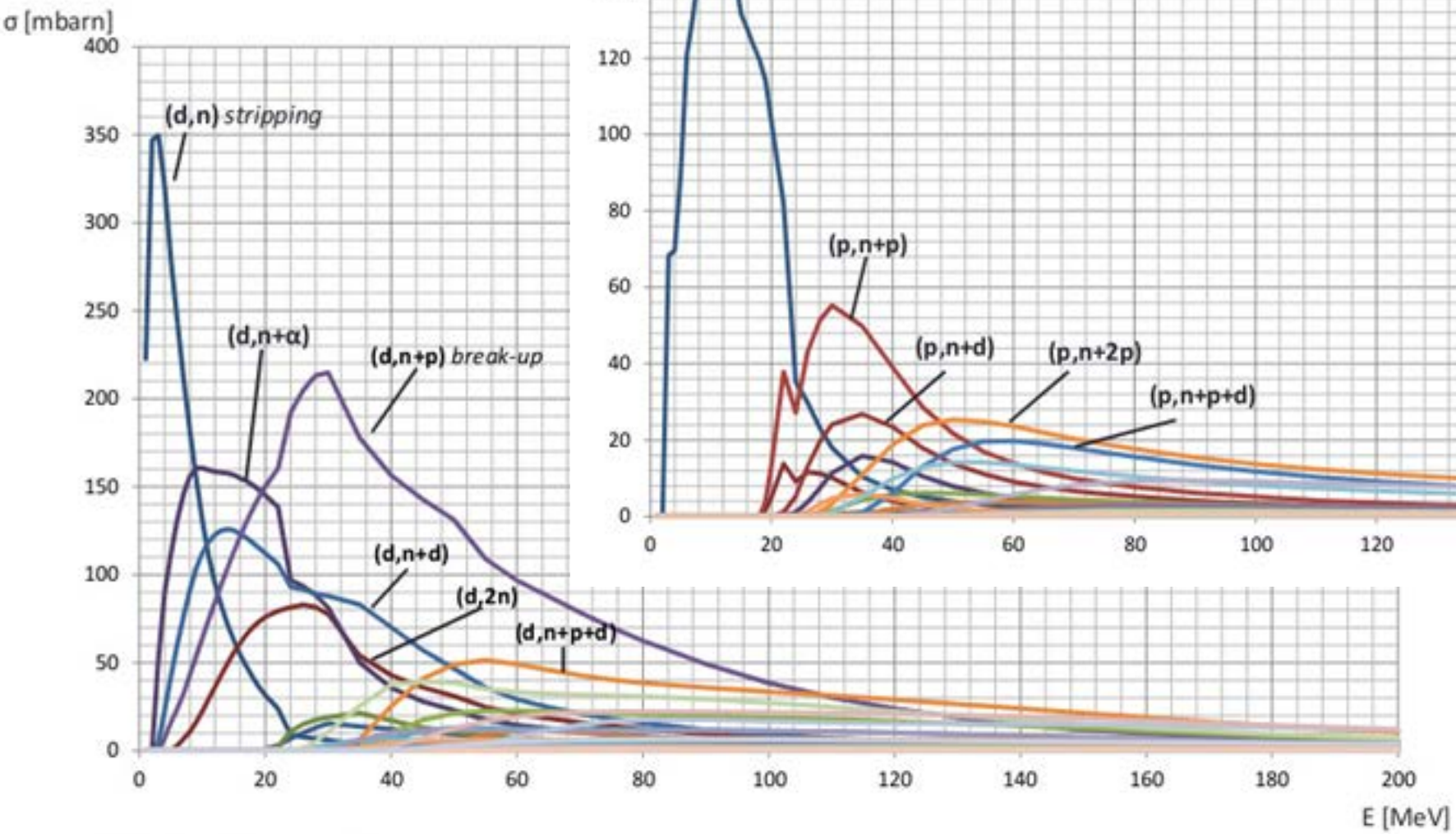


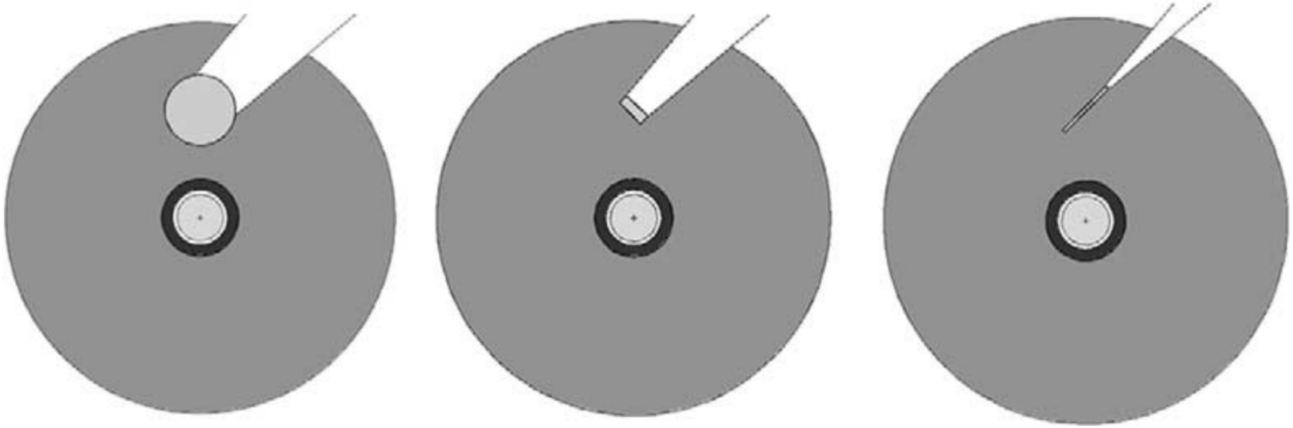


TENDL ^{9}Be(p,xn) REAKTIONEN



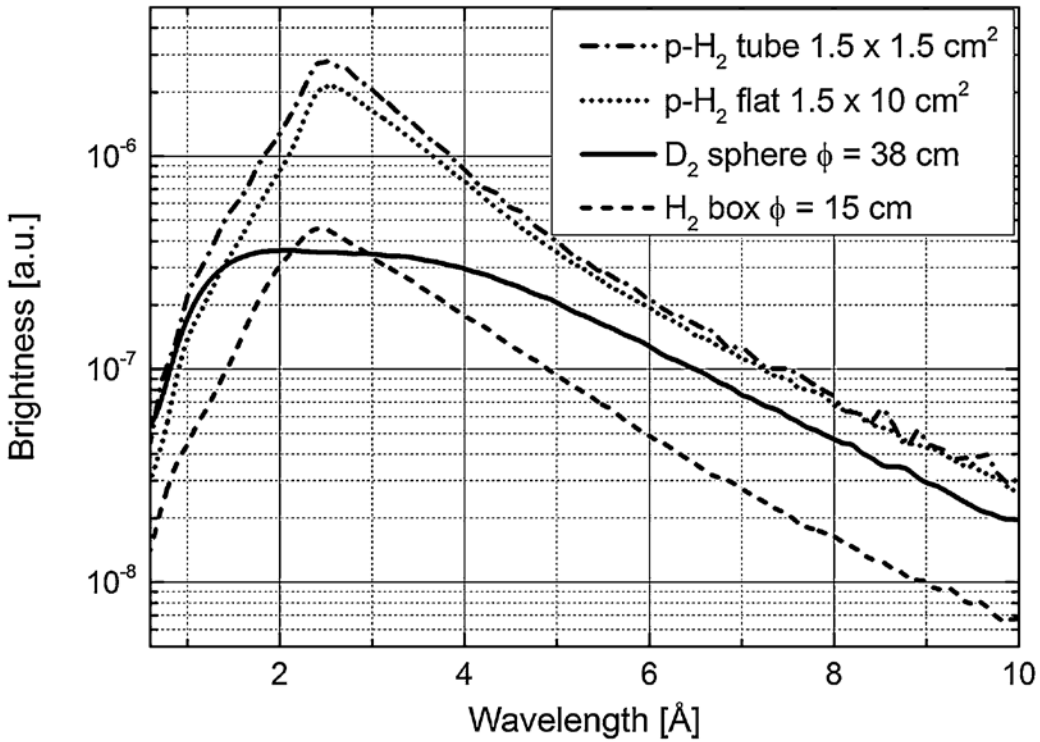
TENDL ^{9}Be(d,xr

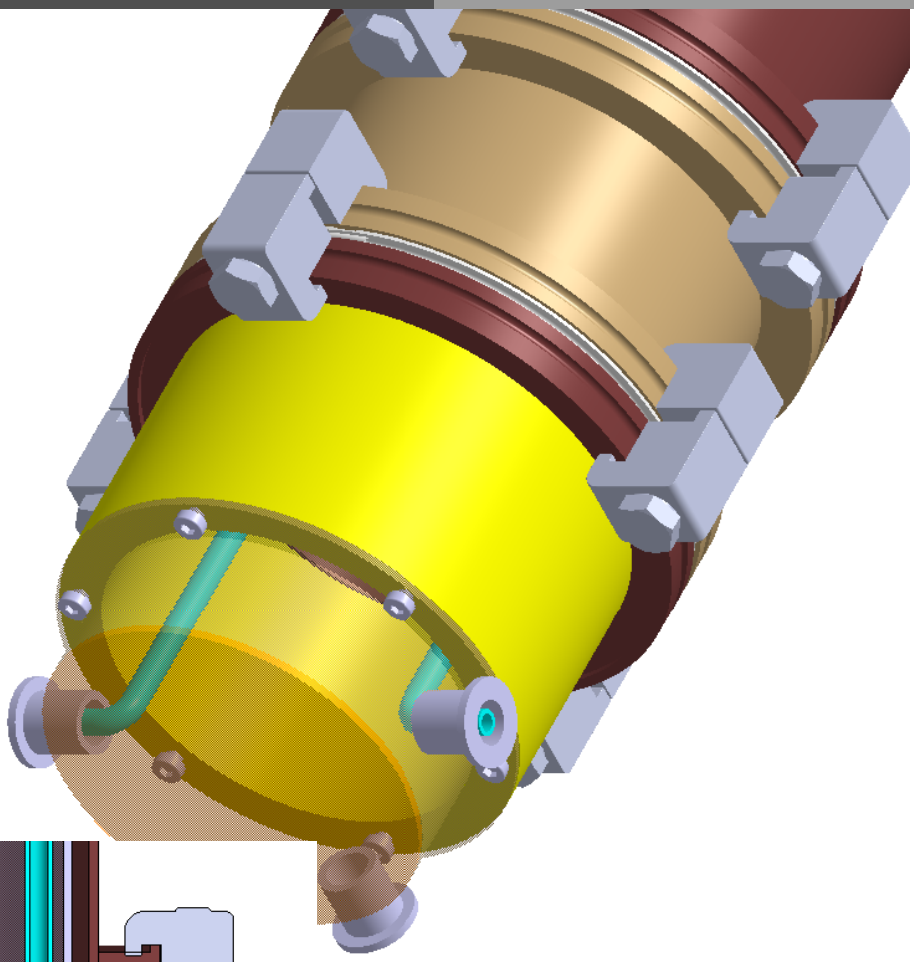


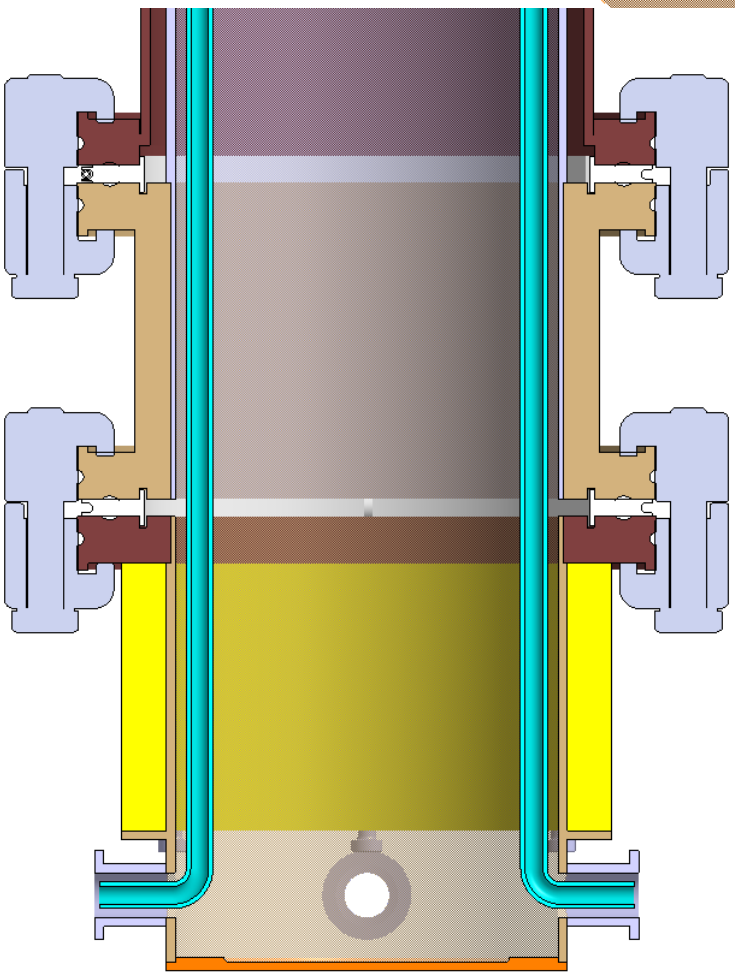


D_2O reflector tank (middle grey) with the active fission zone in the center. Different cold moderators from left to right D_2 sphere, H_2 box, p-H_2 flat and tube moderators.3.)

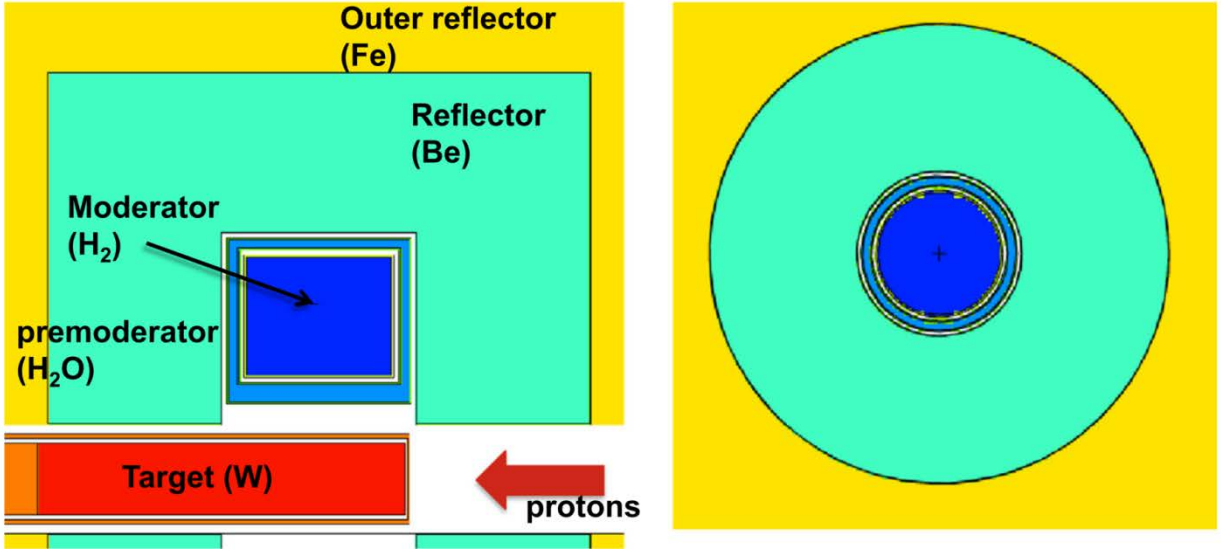
MCNPX simulation results for the relative perturbed neutron brightness of a variety of cold neutron moderators at an ILL type fission reactor with heavy water reflector. The dimensions in the figure define the viewed moderator surfaces. The depth of the rectangular flat and tube moderators is 25 cm. The H_2 box moderator contains 50% ortho and 75% para, and it is 5 cm thick. 3.)

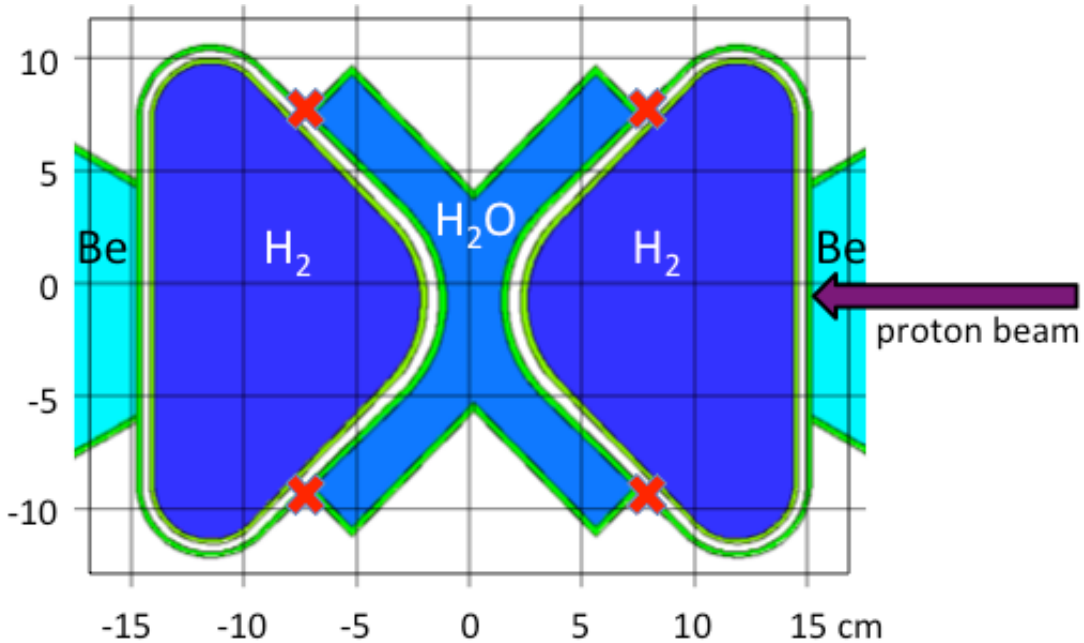




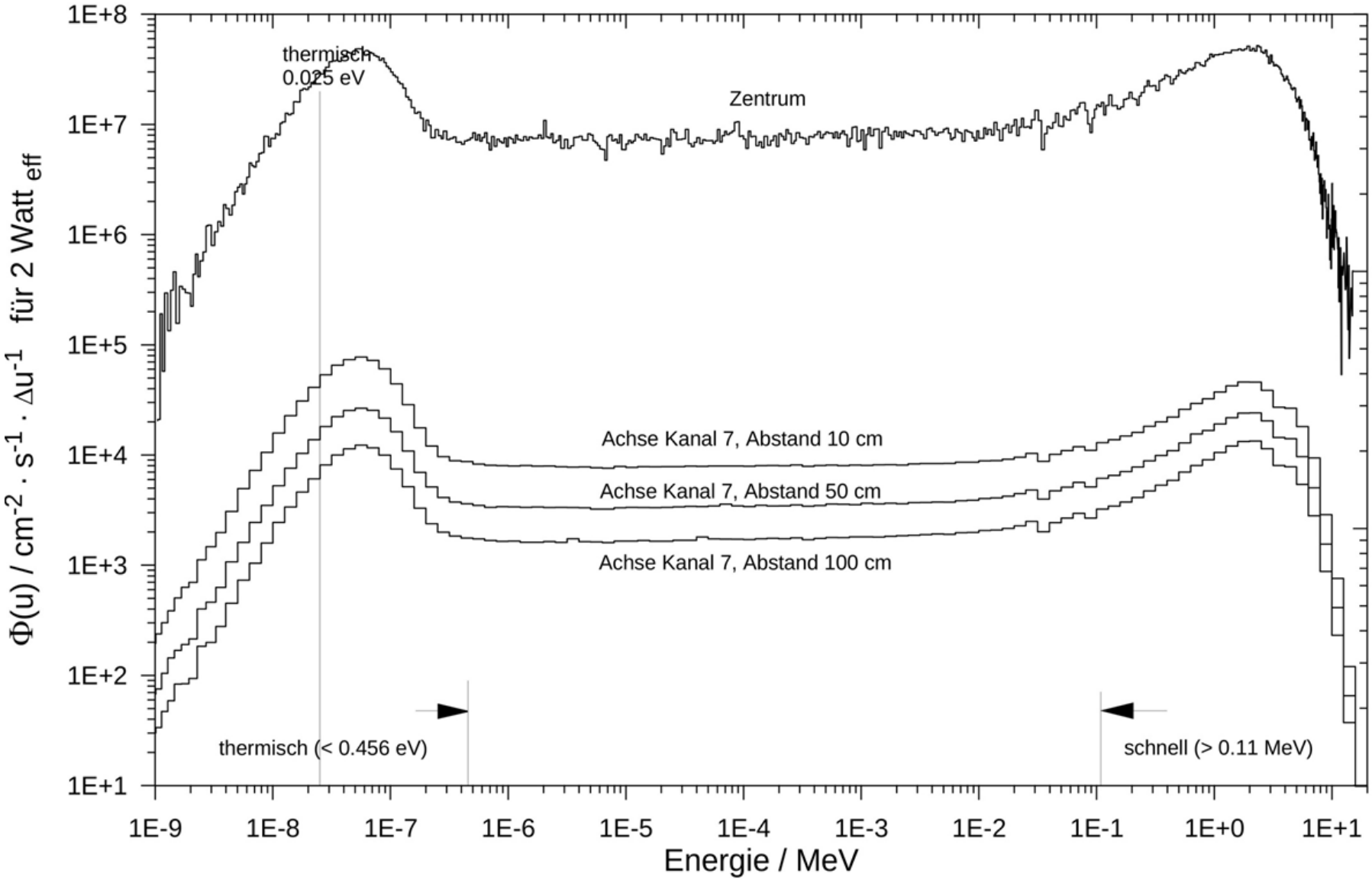


Side view MCNPX model of the unperturbed (left). Top view of the unperturbed moderator (right) 4.)





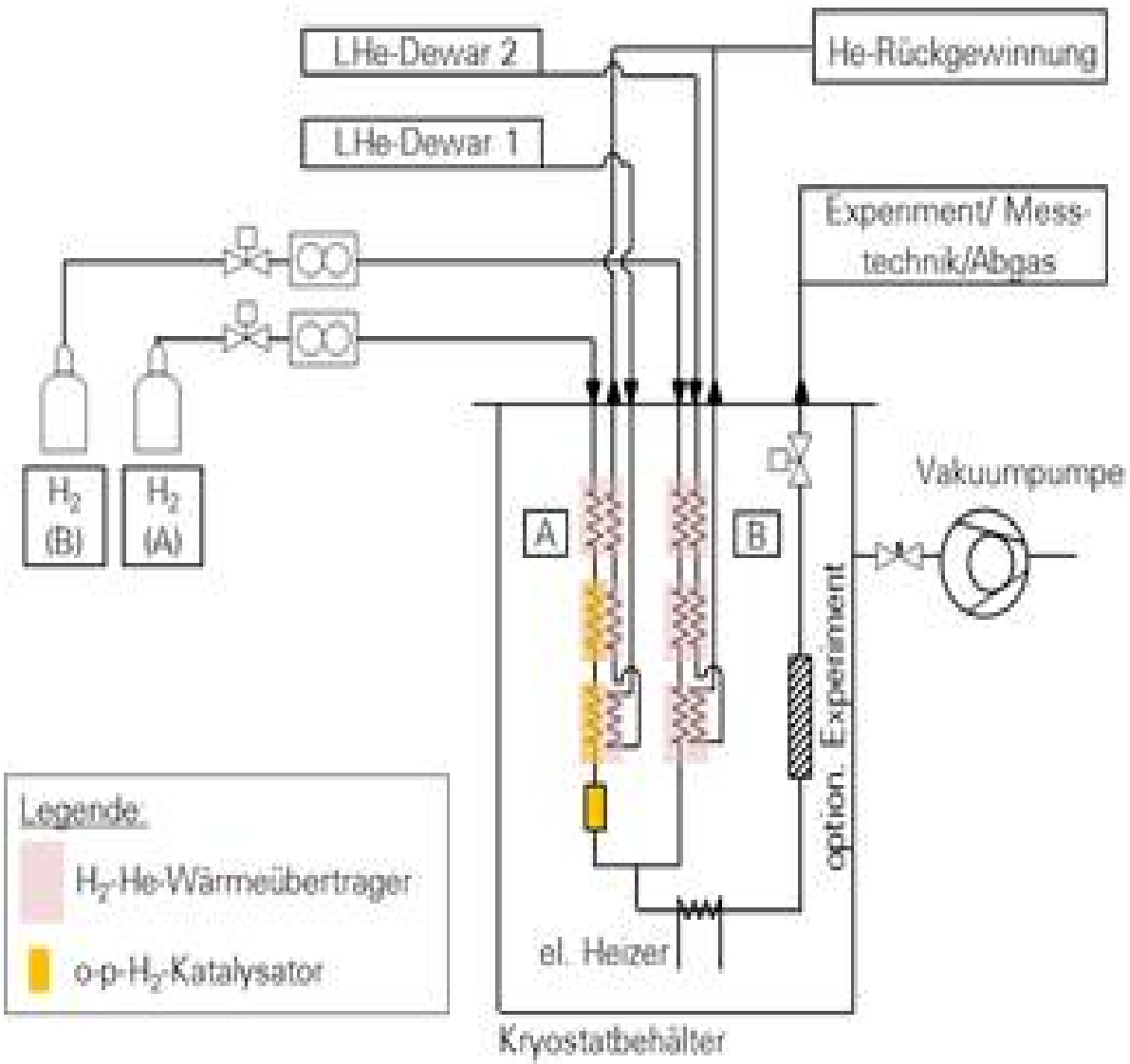
3.) Low dimensional neutron moderators for enhanced source brightness
Ferenc Mezei, Luca Zanini, Alan Takibayev, Konstantin Batkov, Esben Klinkby, Eric Pitcher and Troels Schönfeldt
4.) Unperturbed moderator brightness in pulsed neutron sources K. Batkov, A. Takibayev, L. Zanini, F. Mezei
doi:10.1016/j.nima.2013.07.031

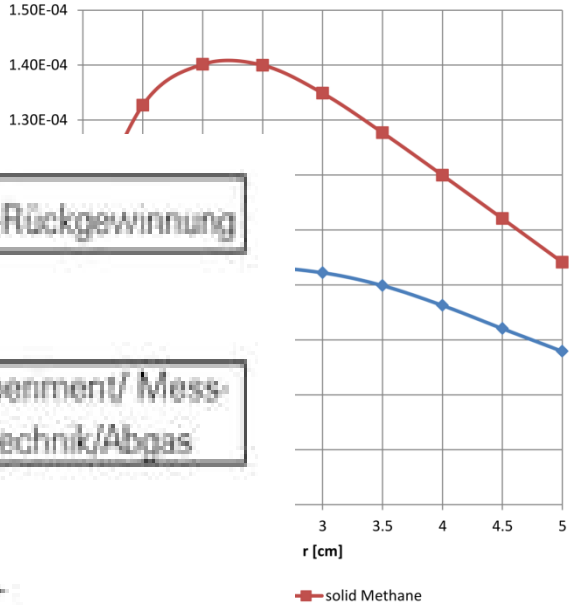


Neutronen-Energieverteilung am radialen Experimentierkanal (MCNP-Rechnung)

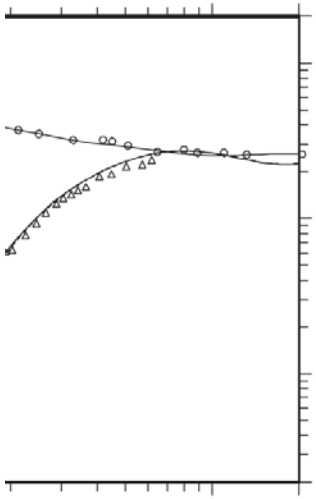
(Cold) moderator

1H
2H
Be
10B
11B
C
O





o/para liquid H_2

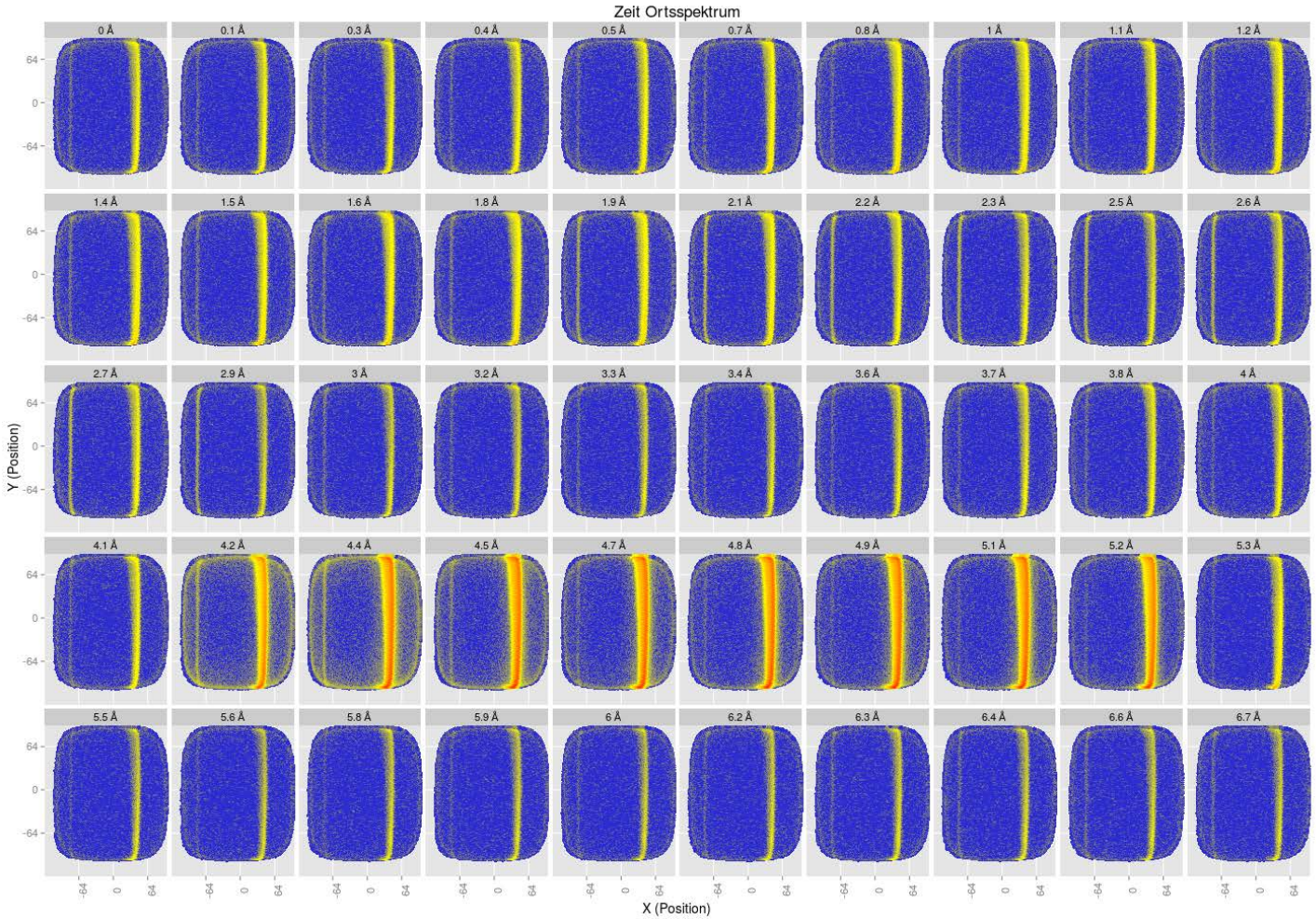


Liquid ortho-H_2 (upper curve) and liquid para H_2 (lower curve) calculated and experimental data at 20K and 14K .) Nuclear Instruments and Methods in Physics Research A 523 (2004) 398–414 Coupled hydrogen moderator optimization with ortho/para hydrogen ratioTetsuya Kai*, Masahide Harada, Makoto Teshigawara, Noboru Watanabe, Yujiro Ikeda

From Neutron News, Vol. 3, No. 3, 1992, pp. 29-37

Workshop status

Chopper & detector



detector
- Li-szintillator
- photomultiplier
- 2D – area
- design and electronics by ZEA 2 Jülich Forschungszentrum

chopper
- 17000 rpm
- Boron covered wheel

space resolution:
- 256 x 256 channels (pixel)
- 0,9 – 3,6 mm² per pixel
- r = 8 cm detector area

time resolution:
- TOF-method
- chopper frequency
- flight path
- min 100kHz signals