PAUL SCHERRER INSTITUT

PSI

Wir schaffen Wissen – heute für morgen

Moderator Studies on Simple Geometries

UCANS-V, Padova, May 2015

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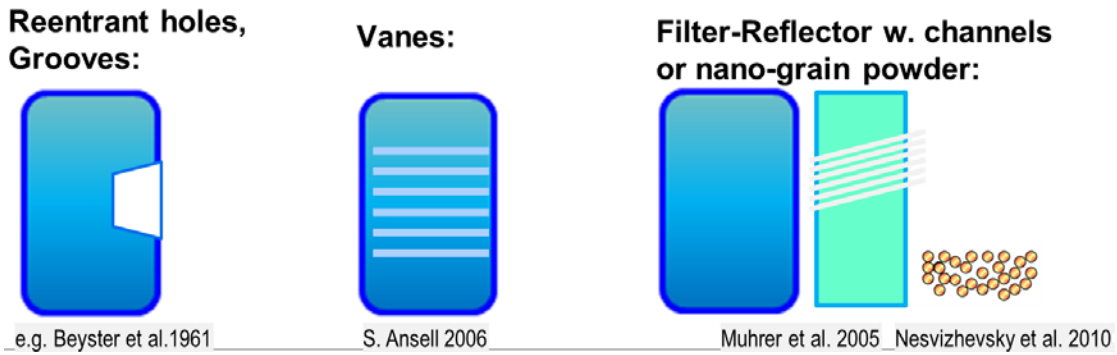
Paul Scherrer Institut

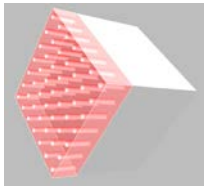
Background, Idea

Measures to enhance output of (cold) moderators have been proven to work:

- Reentrant holes
- Vanes
- Be-reflector/filter
- Nano diamonds



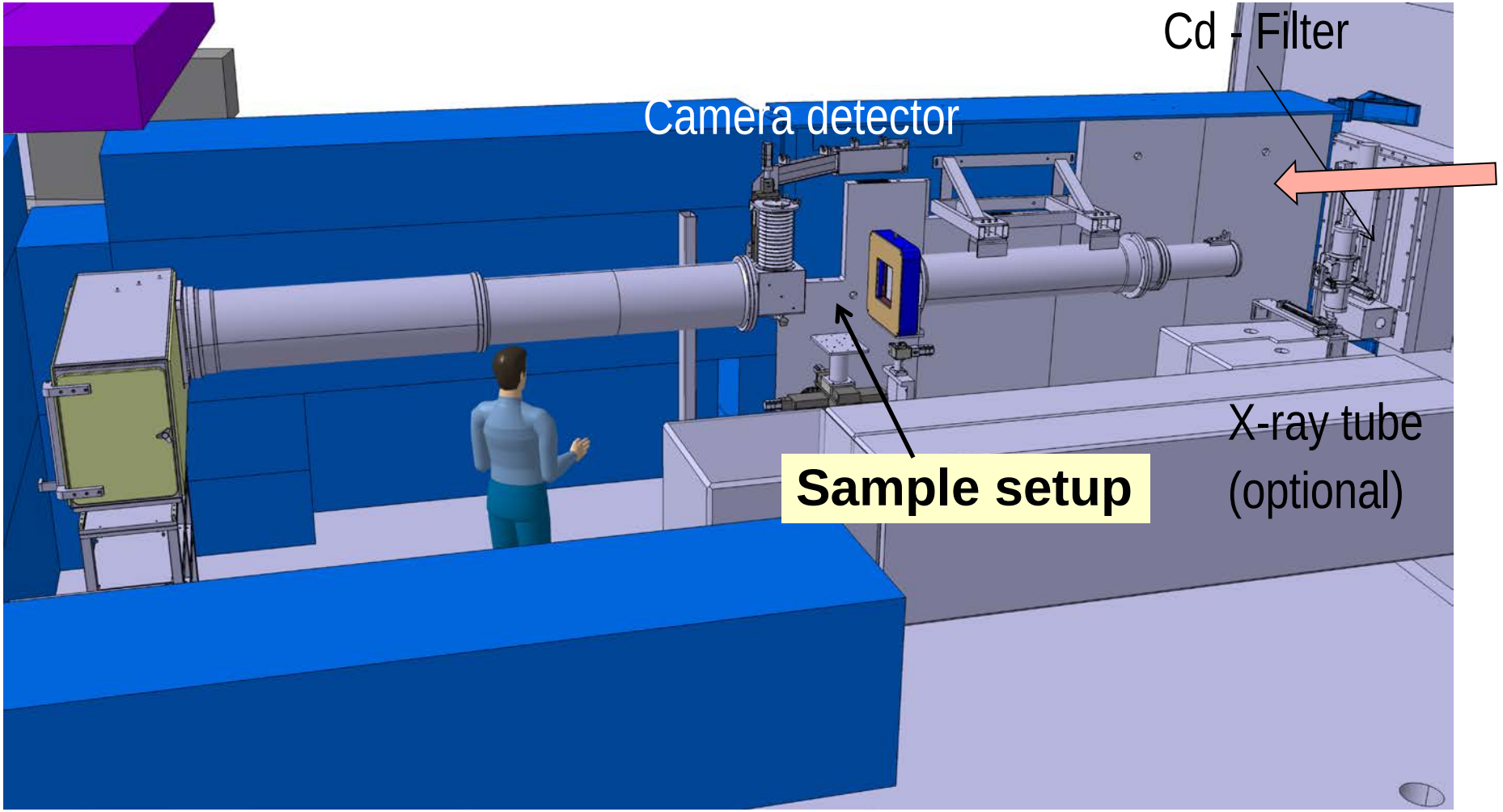
Simple proposal:



Investigate whether similar measures would achieve comparable benefits also on the input-side of a moderator

- First measurements and simulations indicated some effect (ICANS 2014, WCNR 2014)
- Benchmark experiments and calculations on toy-geometries have been continued

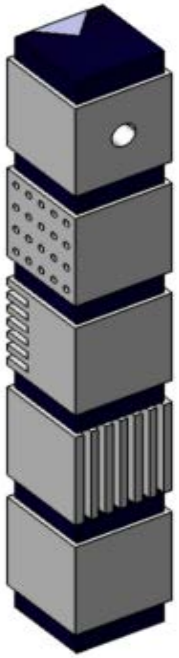
Neutron and X-ray Radiographs taken at SINQ/NEUTRA



http://www.psi.ch/sinq/neutra

Overview of neutron radiography NR measurements

Neutron Radiographs and images sideways at 90º have been taken at SINQ / NEUTRA for simple specimen with diversely structured Polyethylene cubes in various configurations.



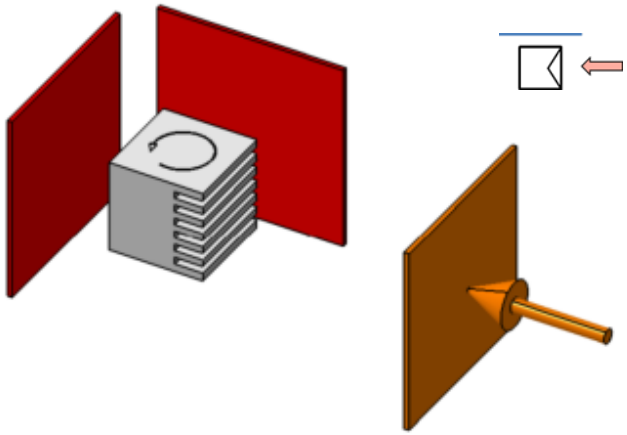
General Remark:

Pictures here are enhanced for best visibility,

numerical values and profiles are as measured and normalized

Measurements were performed with Li-6 ZnS screens, CCD cameras and imaging plates.

Cold, thermal and “fast” neutrons have been employed, the latter obtained by closing a light instrumental shutter.



Representative measurement geometries

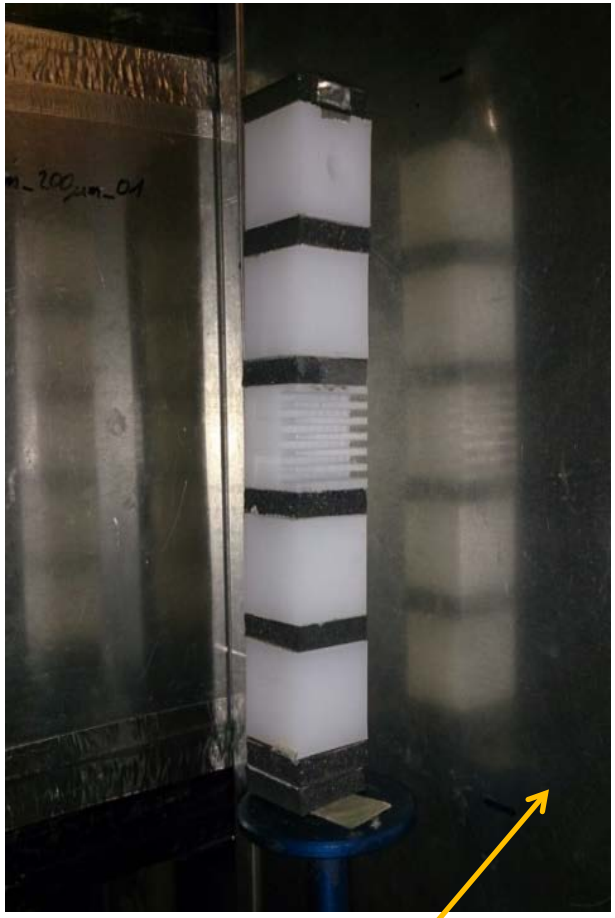
Polyethylen cubes with 2 cm side length and different structures separated by POLY+boroncarbide

Radiography

Through-holes

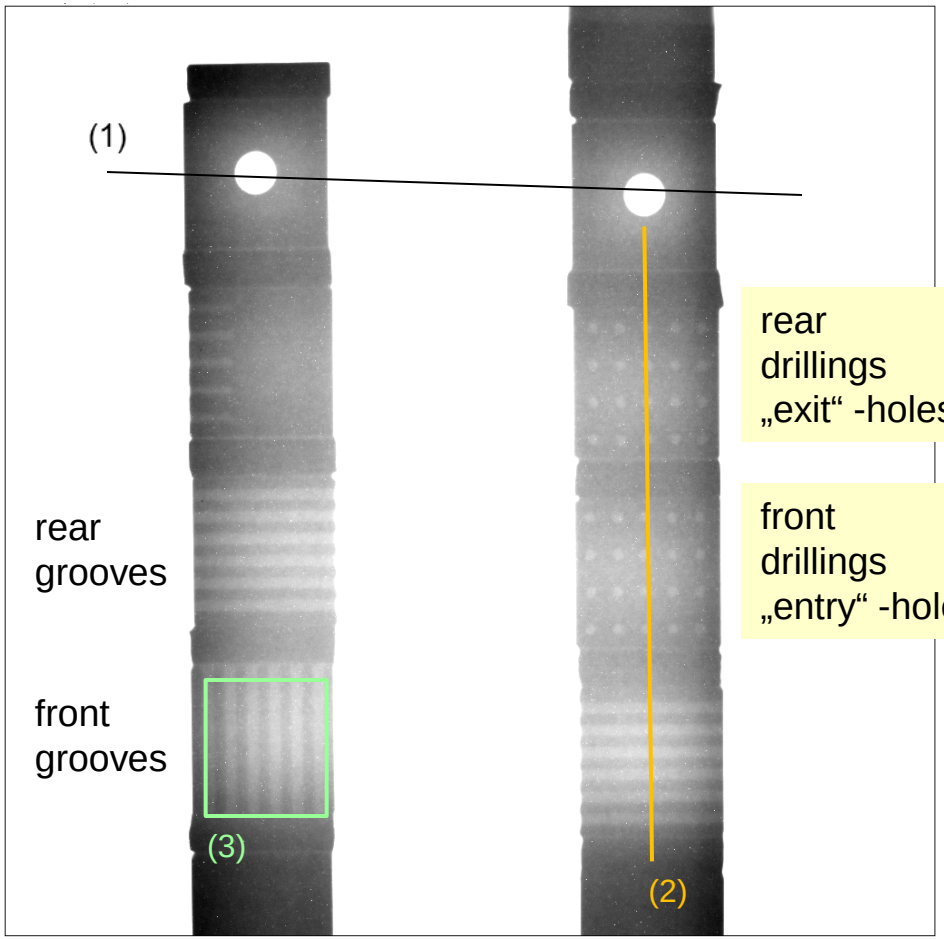
Drillings 1.5 x 6 mm
& Grooves 6 mm

Full cubes

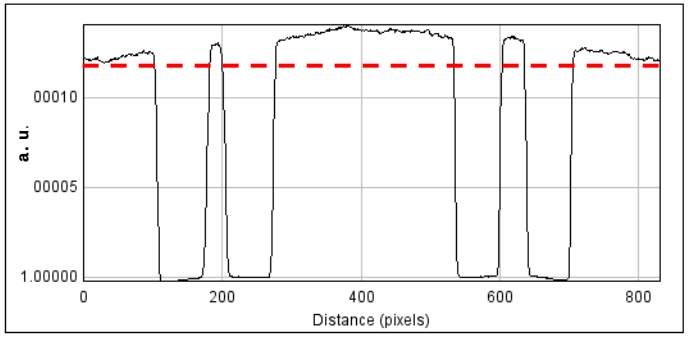


Sideways Detector

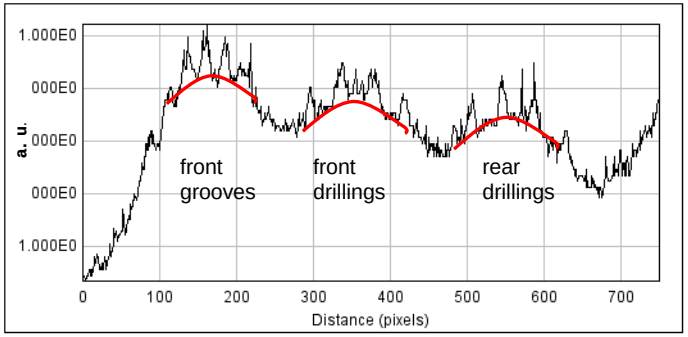
Thermal neutrons radiography, det. NEAR (serie1)



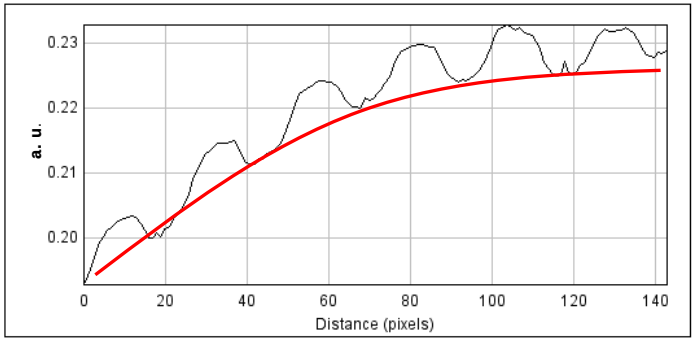
Profile through both through-holes (1):



Profile from bottom to top (2):



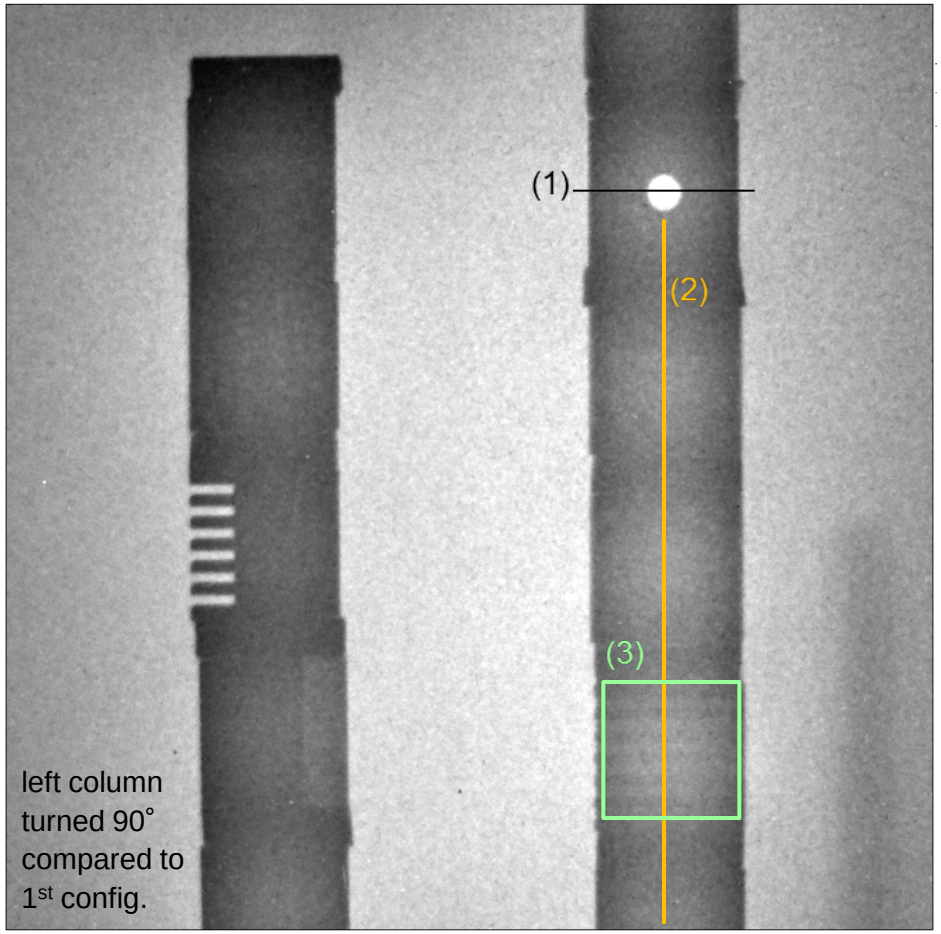
Vertical projection along grooves (3):



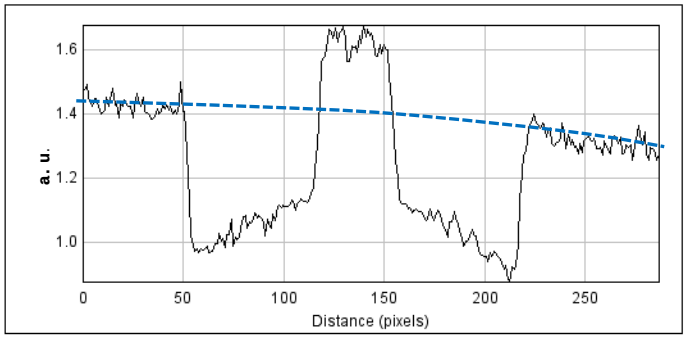
- **non-flat overall field**
- **scattering clearly visible**
- **=> not only modulation by attenuation**

  15% less material → > 50% enhancement
- **similar for front and rear drillings / grooves**

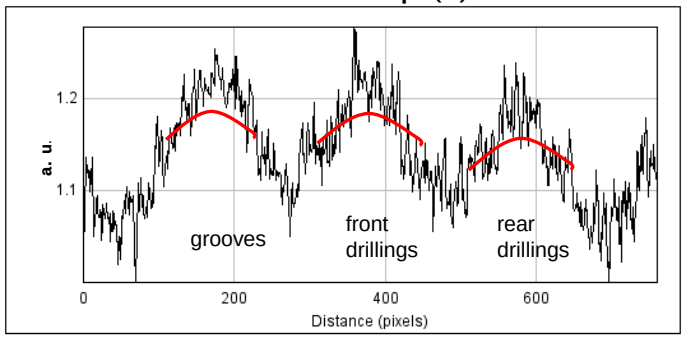
„Fast“ neutrons radiography, det. NEAR (serie9)



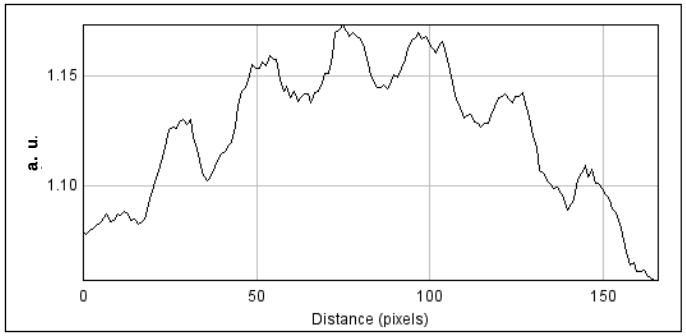
Profile through trough through-hole (1):



Profile from bottom to top (2):

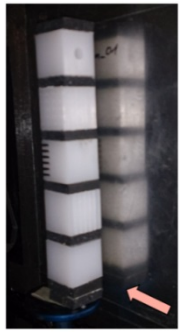


Projection along grooves (3):

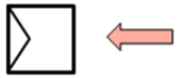


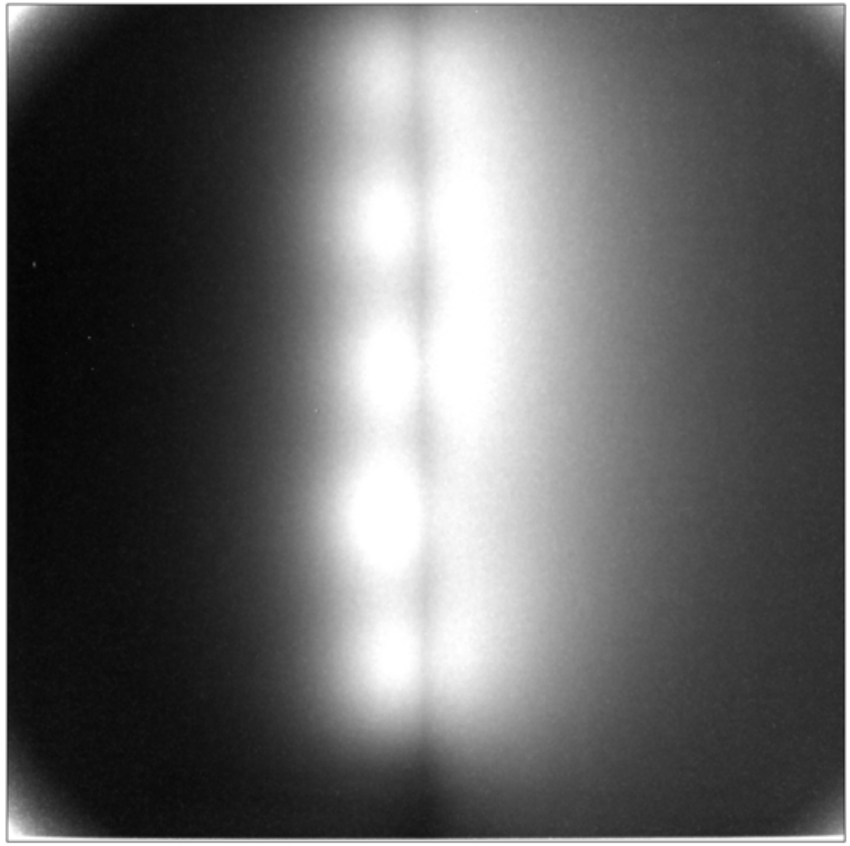
- **hole is brighter than empty field**
- **scattering clearly visible**
- **not only modulation by attenuation**
- **similar for front or rear drillings (~%)**
- **non-flat overall field**

Sideways measurements I



Input:
thermal neutron beam





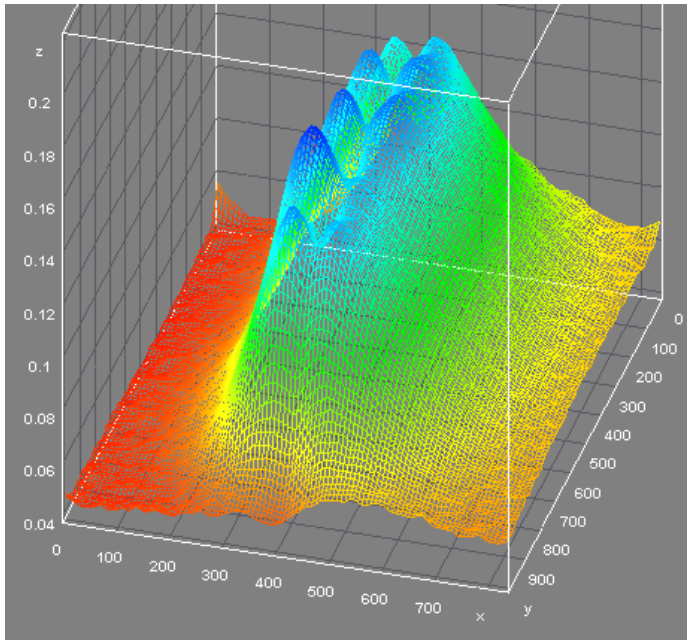
through-hole Along (5)

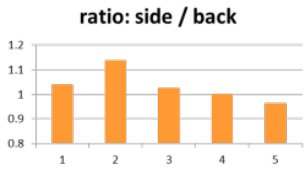
holes away from det. (4)

horiz. grooves Rear (3)

vertical grooves Front (2)

full cube (1)

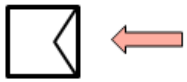


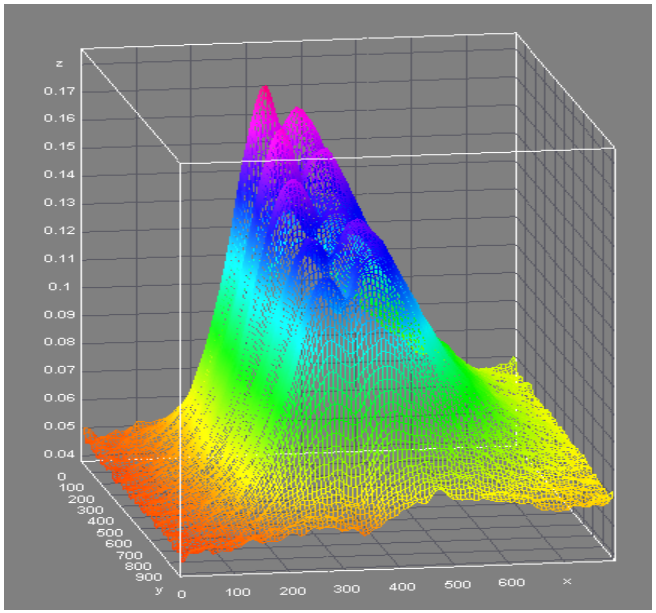


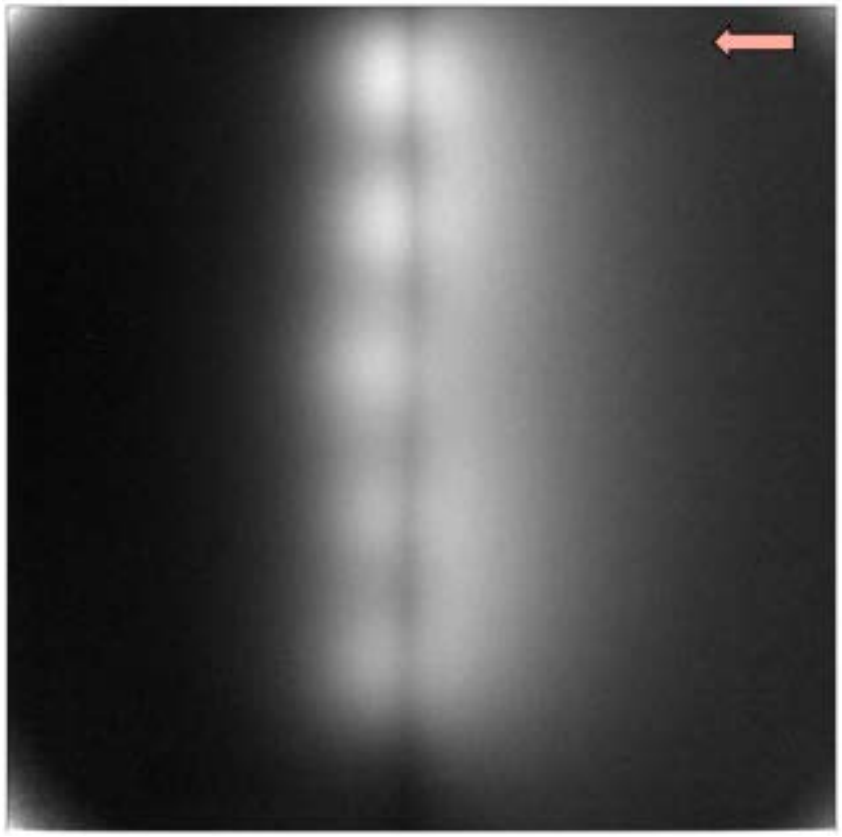
Most neutrons scattered to the side are detected for the cube with grooves facing the incoming beam (position 2)

Turning the specimens by 180°: Sideways measurements II

Input:
thermal neutron beam







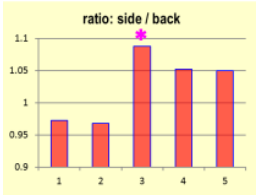
through-hole along

holes 2 det.

horiz. grooves front

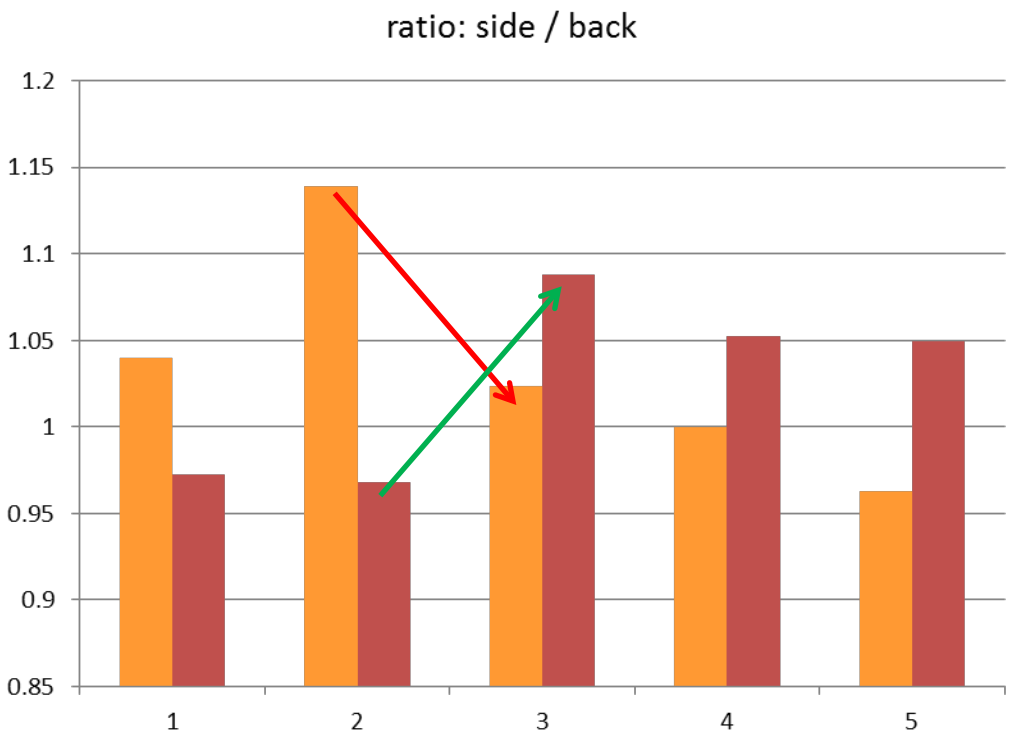
vertical grooves rear

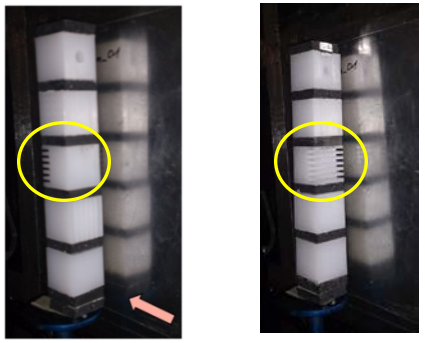
full cube



Most neutrons scattered to the side are detected for the cube with grooves facing the incoming beam (position 3)

Sideways measurements III





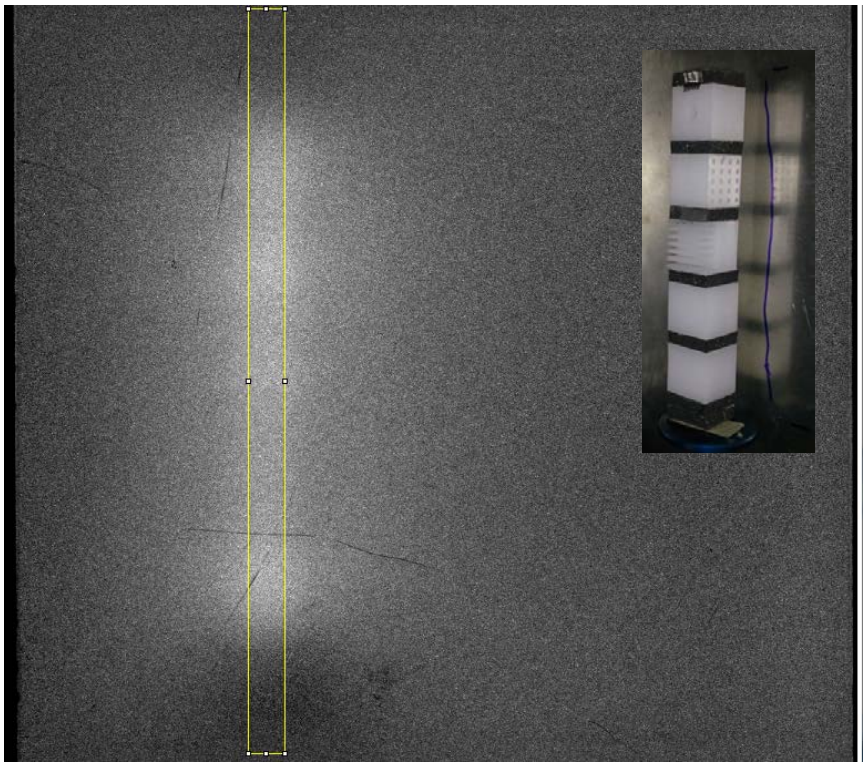
Same column of specimens, in two orientations, i.e., before and after turning by 180 degrees;

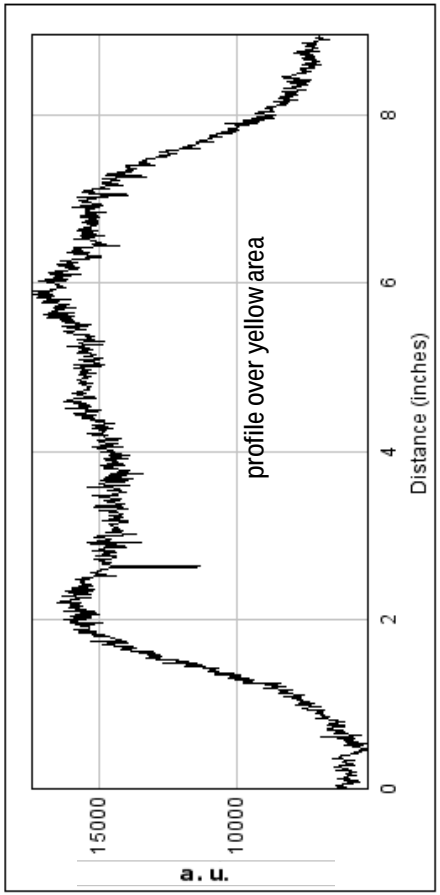
=> “entry-”grooves swapped from position 2 to 3

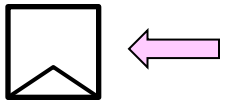
- **Most neutrons are scattered to the side from the cubes with grooves facing towards the incoming thermal neutron beam**
- **Few neutrons are “directly reflected back” from the same positions**
- **More neutrons are detected from “reflection” than scattered to side through the cubes**
- **There is a clear distinction between these two detected fractions**

„Fast“ neutrons, image plate at the side (serie15)

(thermal background substracted but not corrected / normalized)







through-hole in cross dir.

entry-holes ✱

fhorizontal grooves towards det. (a)

vertical grooves away from det. (b)

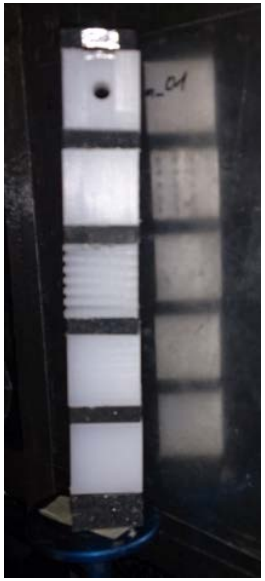
full cube

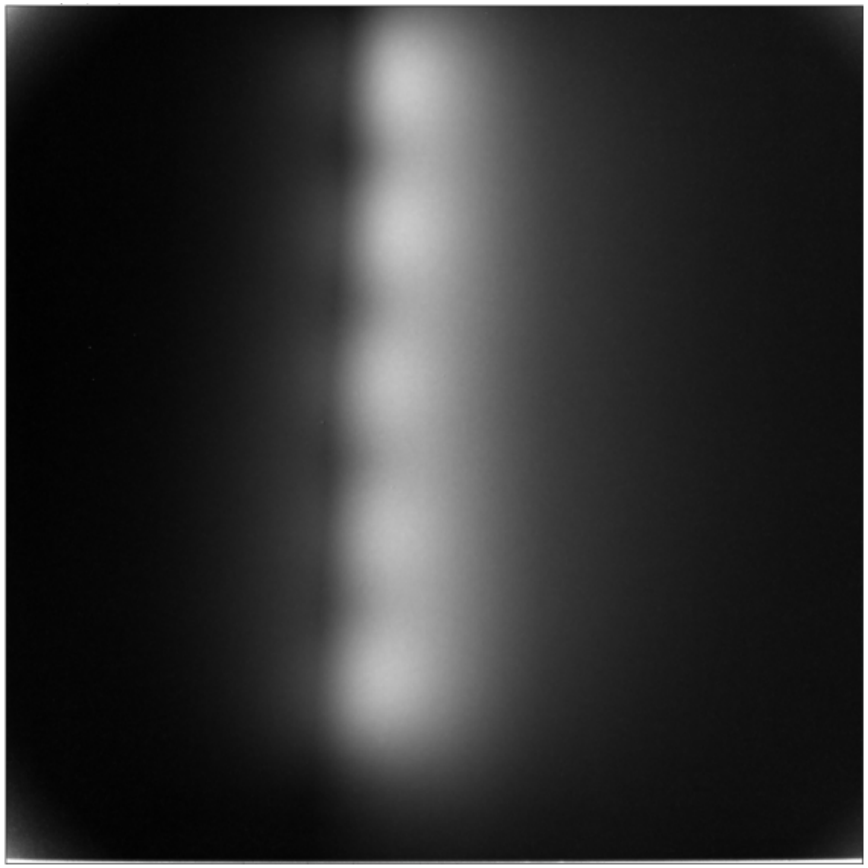
shadow of support

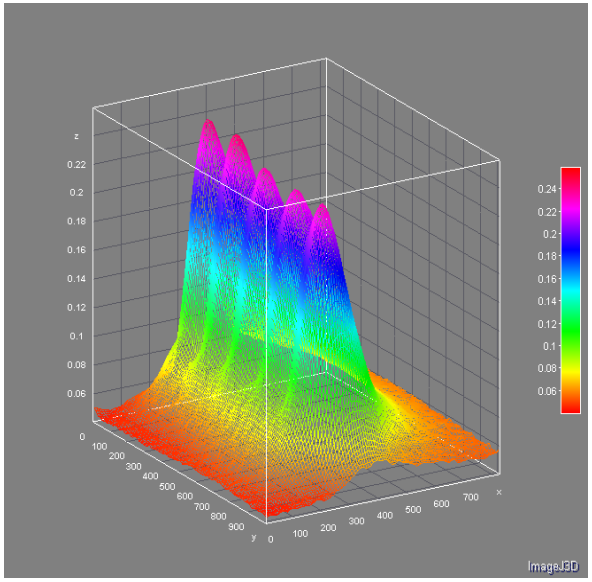
- **little direct backscattering**
- **exit-holes (and through-hole) show some effect**
- **a little more flux to the side for full cube compared to grooved ones**
- **entry-holes and grooves show effect, i.e., enhancing (a) and „draining“ (b)**
- **dissimilar and not so clear situation for “fast” neutrons’ input**

Thermal input

Sideways measurements IV



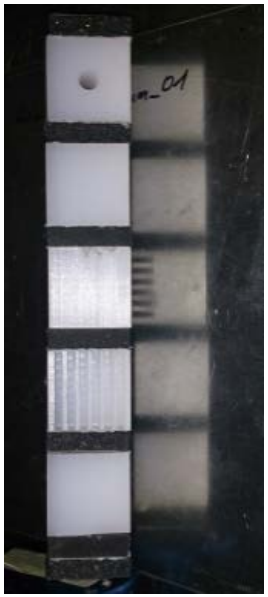


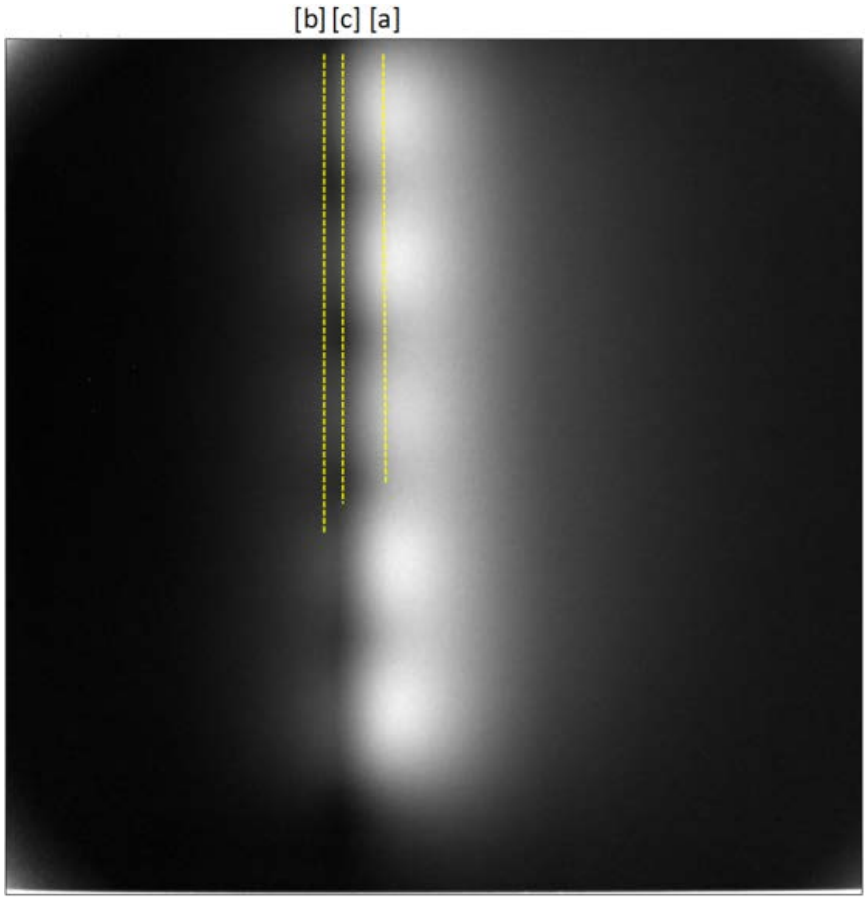


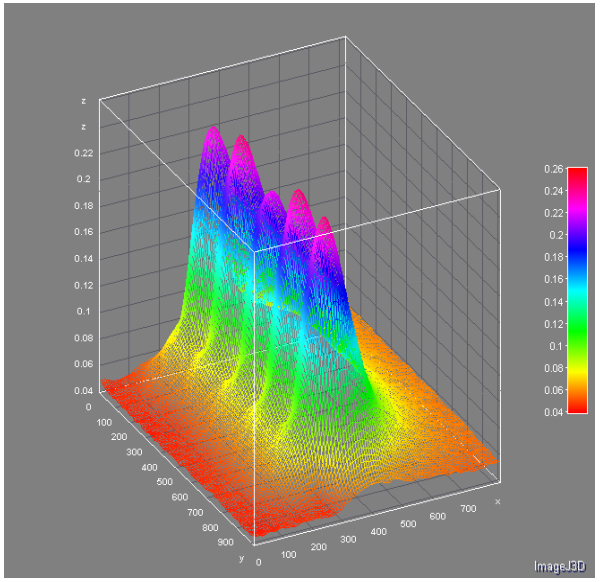
For specimens facing the incoming beam as well as the detector at 45º, the overwhelming fraction of the neutrons hitting the POLY cubes is scattered back (drillings, 9% of the area, have little impact, position 4,
--- input + output effects “cancel”, i.e., Δnetto = 0**)**

Thermal input

Sideways measurements IV

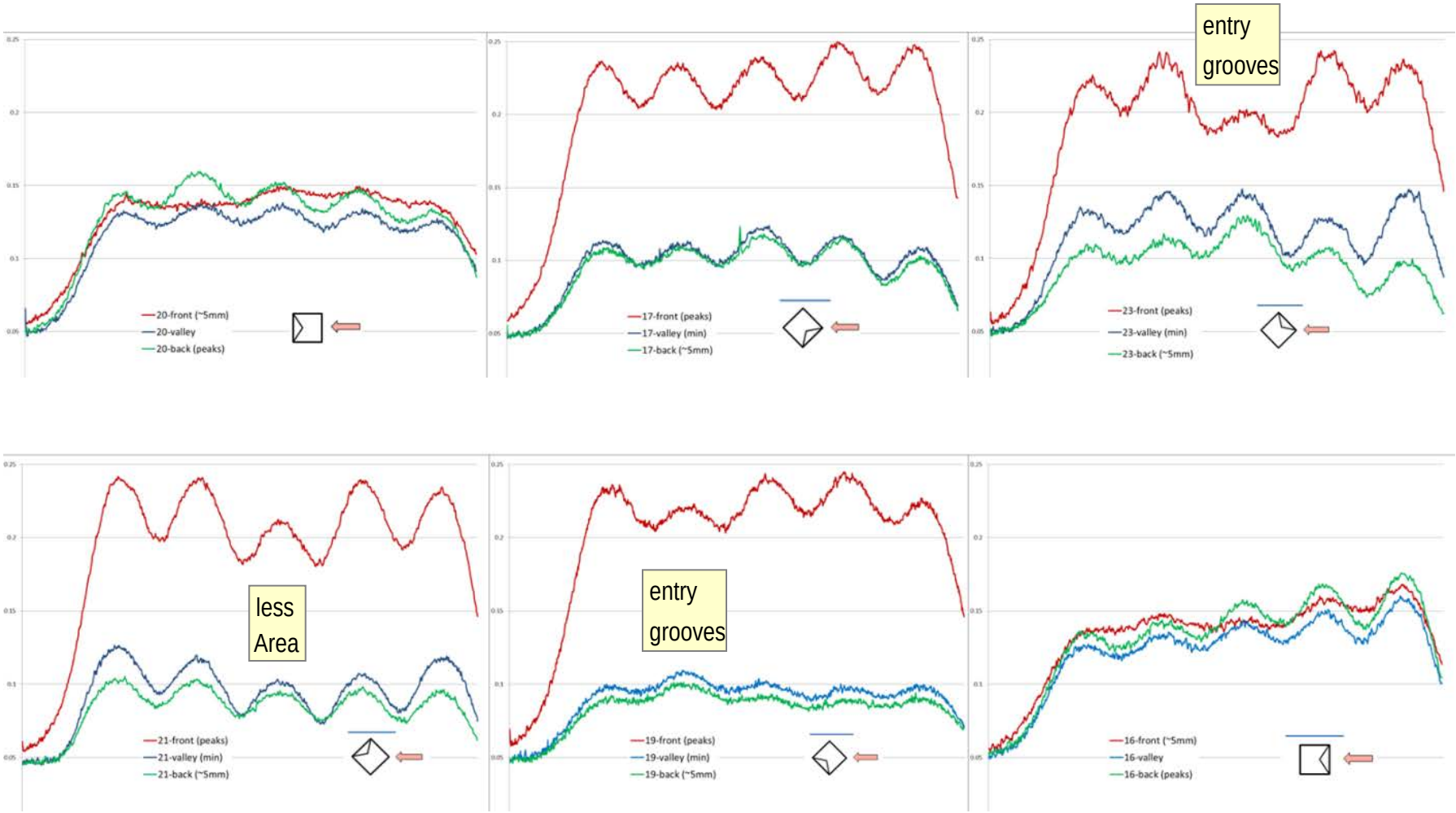






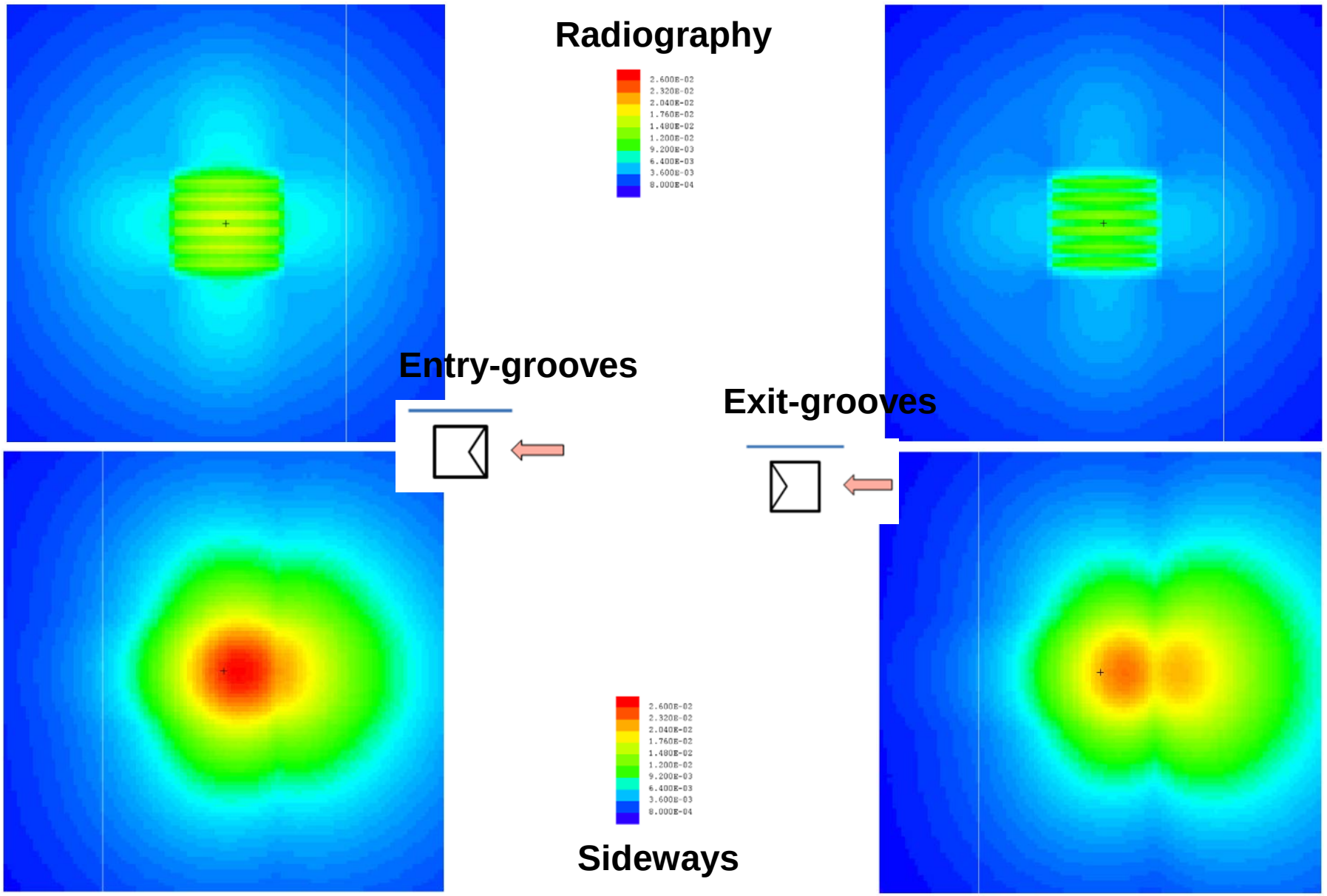
For specimens facing the incoming beam as well as the detector at 45º, the overwhelming fraction of the neutrons hitting the POLY cubes is scattered back (the reduction in exposed area 13.5% is visible, position 3)

Thermal input Sideways measurements V

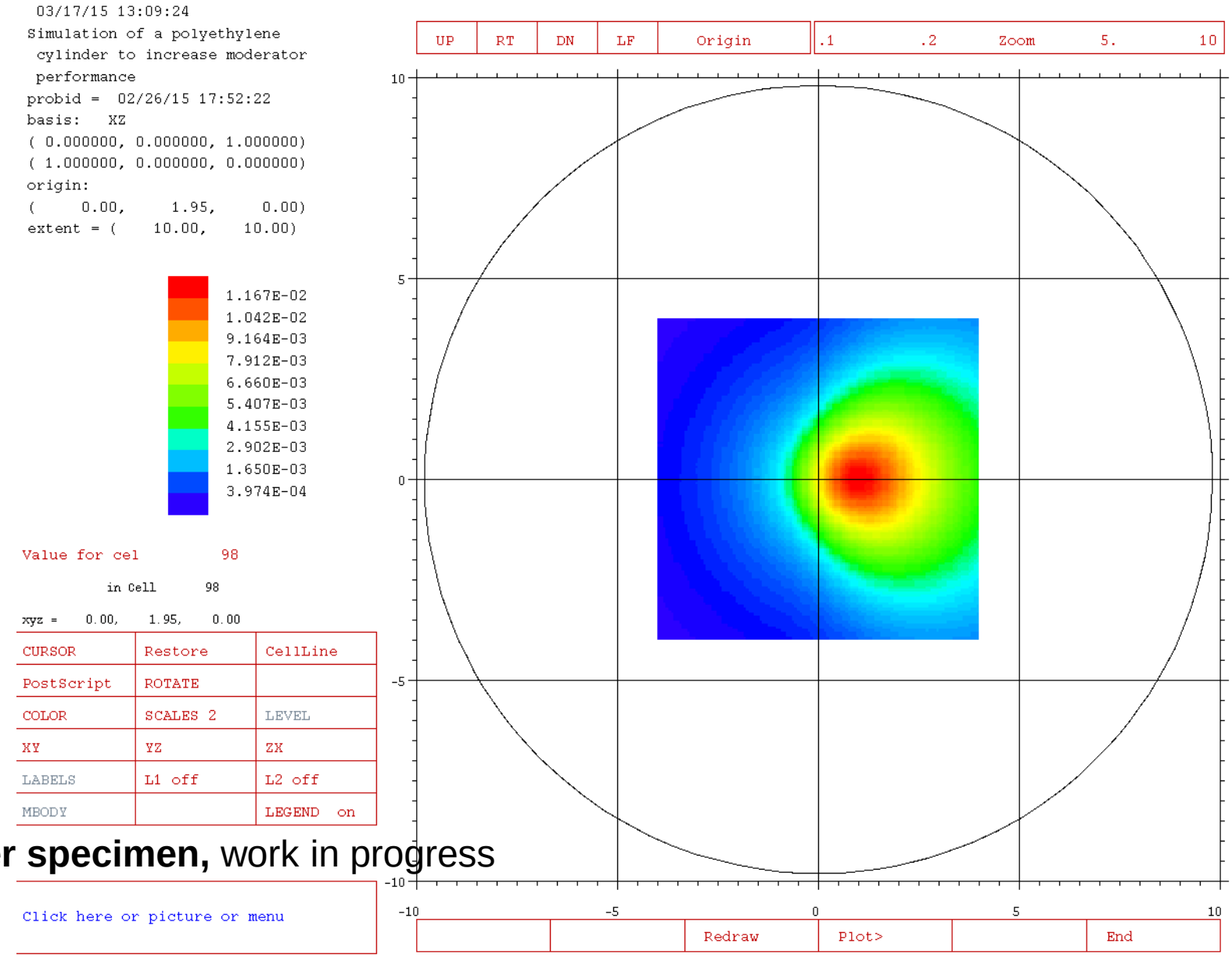


For specimens facing the incoming beam as well as the detector at 45º, the overwhelming fraction of the neutrons hitting the POLY cubes is scattered back and the effect of structuring is evident

Simulations for thermal input



example Simulation for Fast Input



Cylinder specimen, work in progress

this is work in progress, Preliminary Conclusions

- **Evidence for enhanced coupling to the neutron field due to stucturing has been found for input *into* and output *out of* moderator material**
- **Effects for „entry-“ and „exit-“ grooves are similar**
- **Most thermal neutrons are directly scattered back**

- **There are differences for thermal compared to „fast“ neutrons**
- **More measurements and simulations are planned,**

  cooperations welcome ! (? „fast“ neutrons @ a CANS ?!)

- **(much) more work is still needed for impact on real moderator design**

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Thanks for many inspiring discussions and help go to our colleagues, in particular,

E. Kästner, A. Kalt, E. Lehmann, M. Morgano, P. Vontobel, and more

Thank you for your attention !