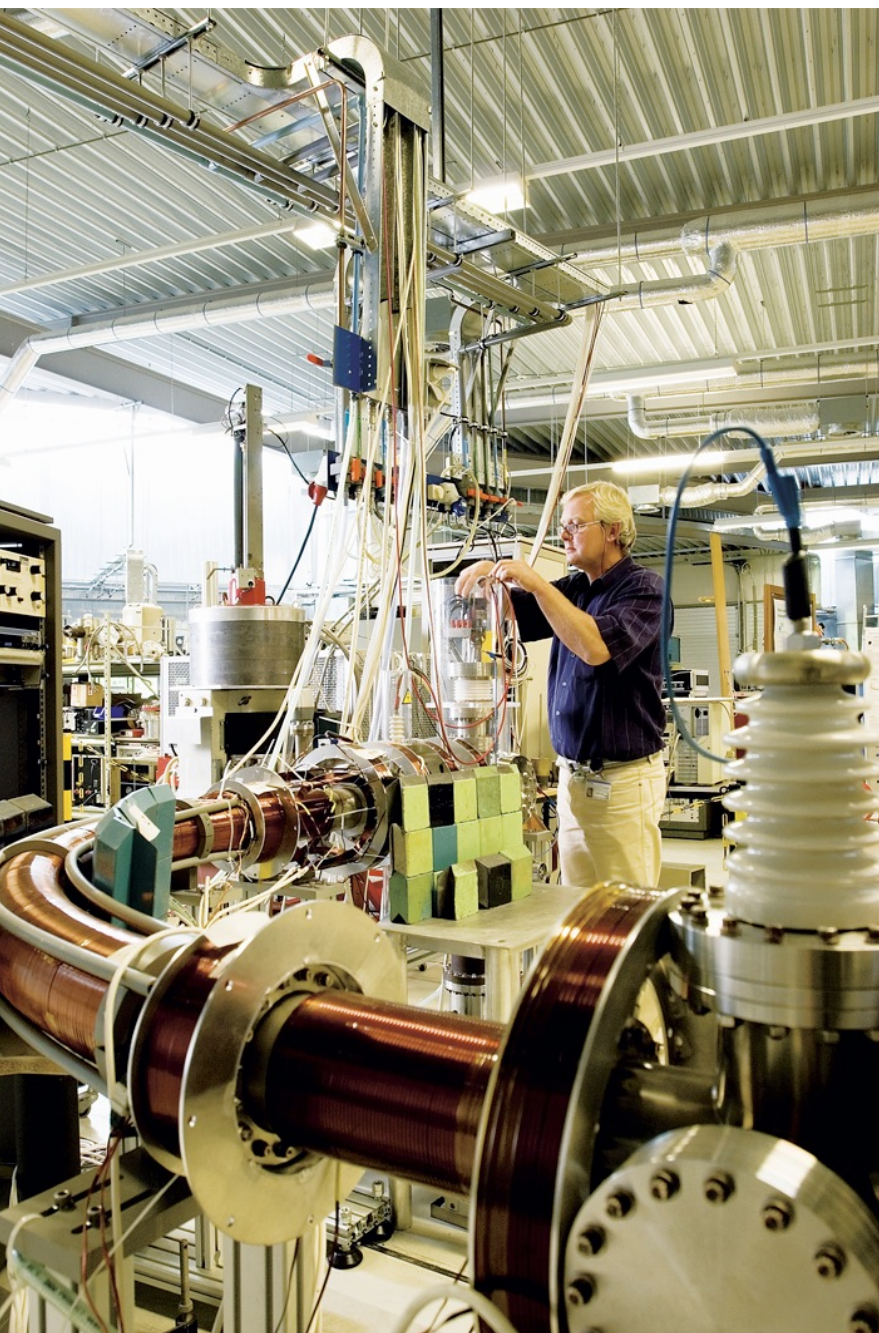


Neutrons at the Research Reactor of the TU Delft

Catherine (Katia) Pappas

RST – NPM2
TUDelft

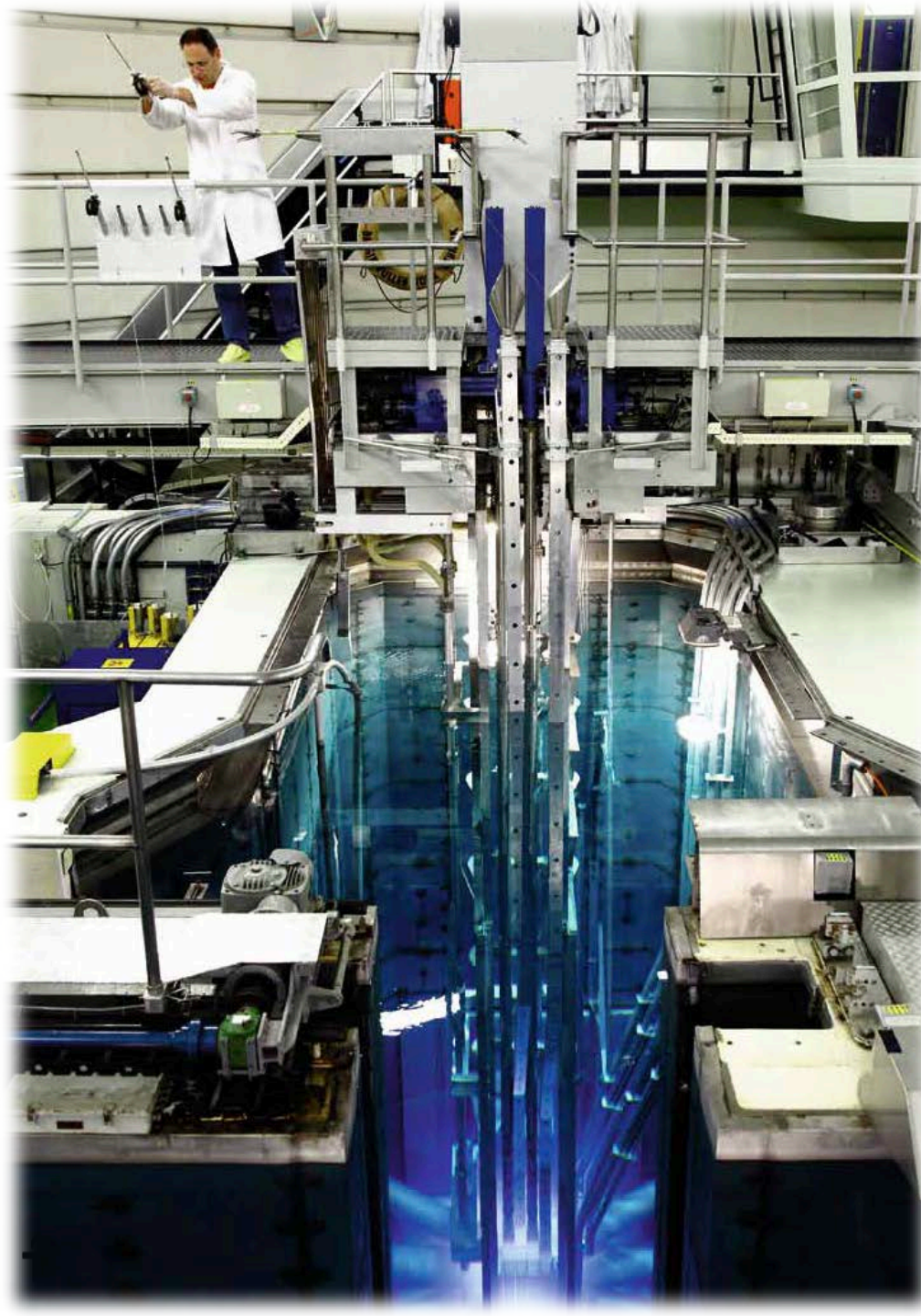


IO Dent



Tradition in methodological developments



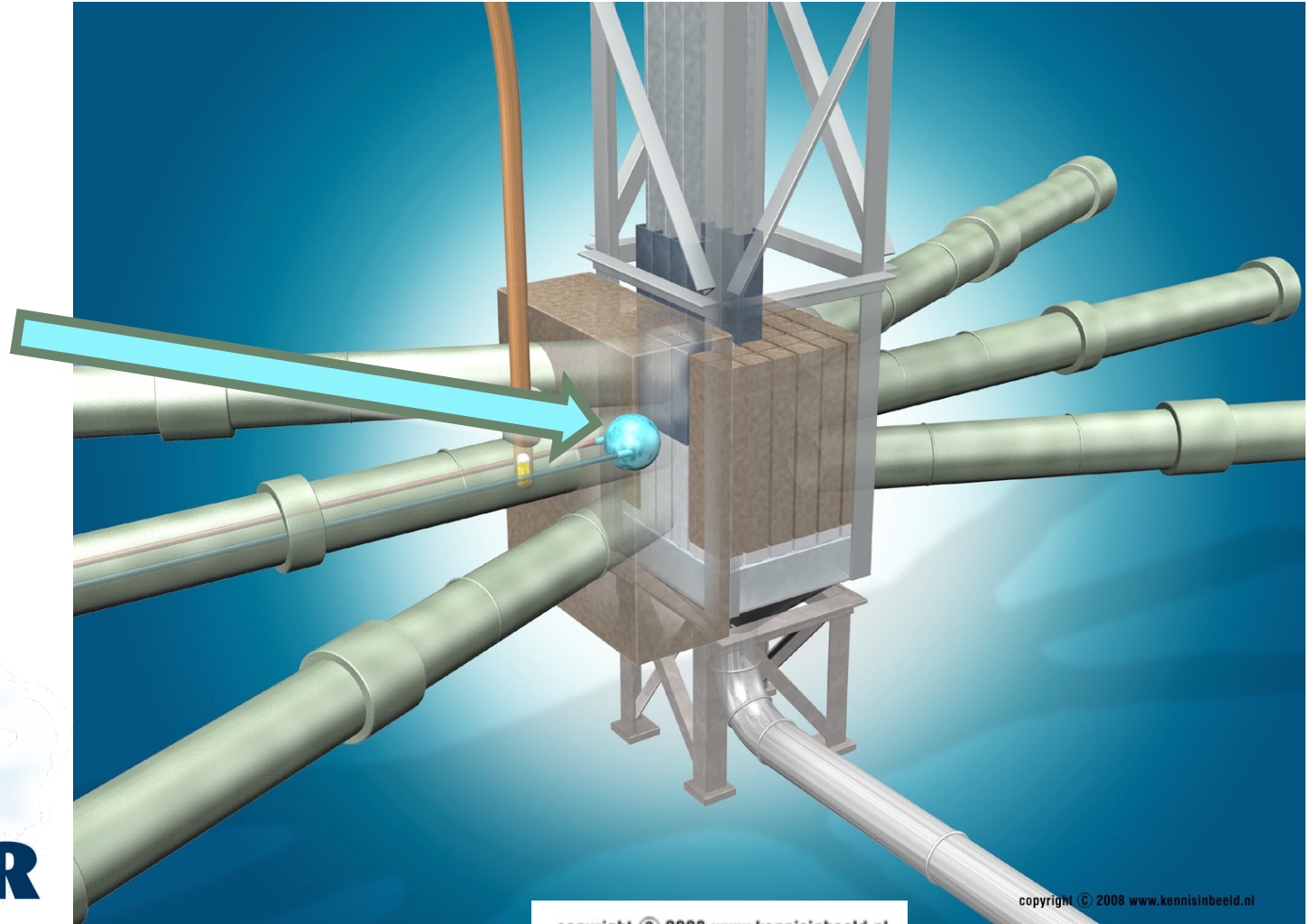


2 MW reactor
No cold source



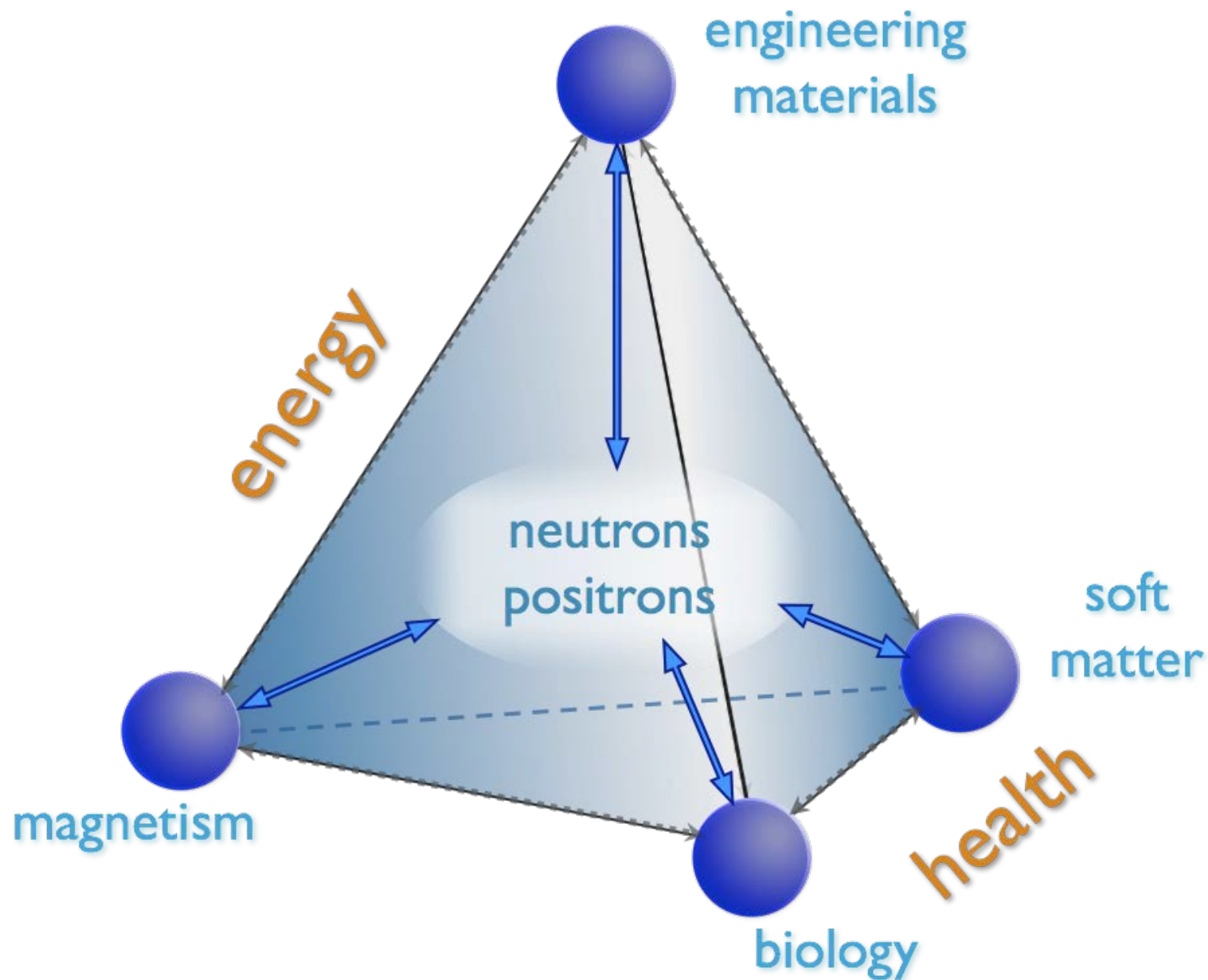
Optimized Yield for Science, Technology and Education – of Radiation

Cold
Source
at R2

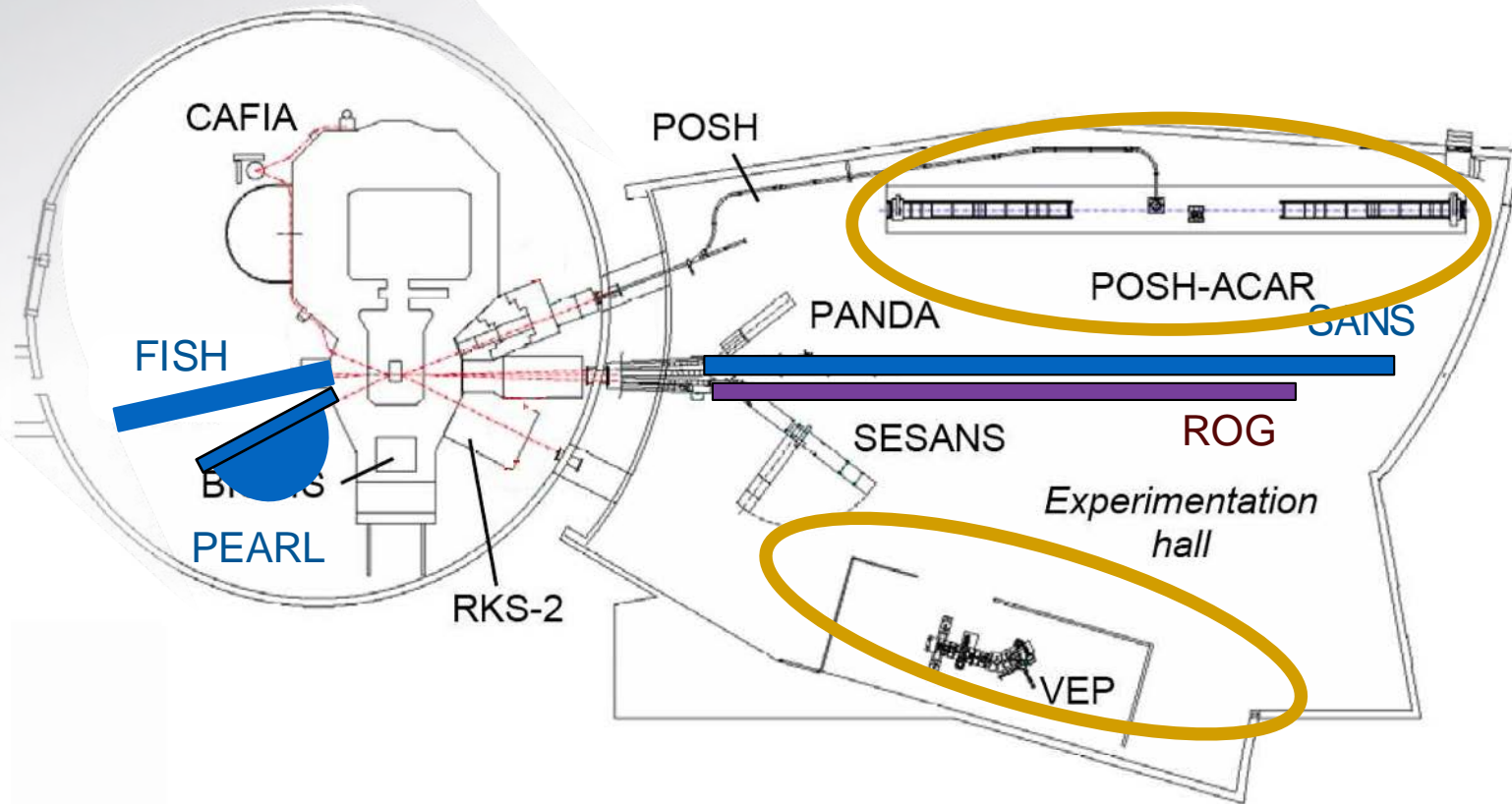
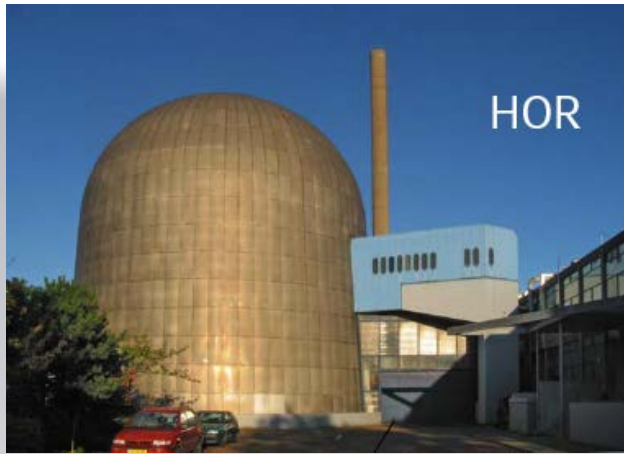


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neutrons - positrons



Neutron Depth Profiling

uses Neutrons of course...

is quantitative and non destructive.

- measures absolute amounts of isotopes such as ^3He , ^6Li , ^{10}B and ^{14}N .
- obtains concentration Profiles as a function of Depth for these isotopes.

based on the nuclear reaction:



A: ^3He , ^6Li , ^{10}B or ^{14}N

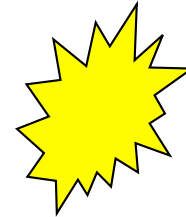
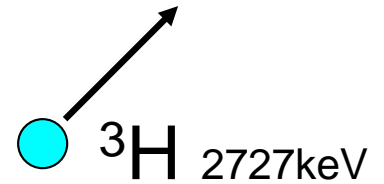
n_{th} : thermal neutron

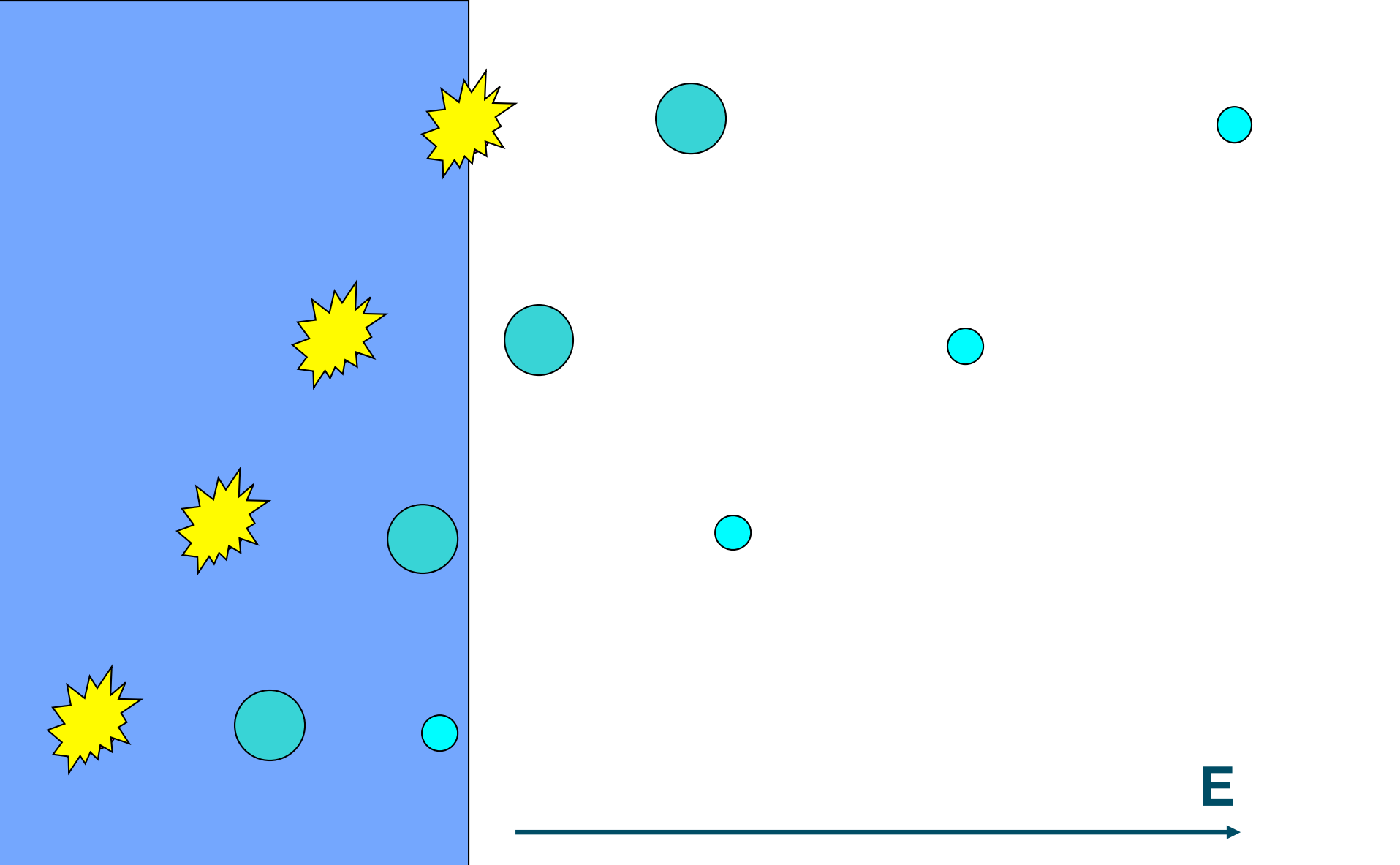
b: proton or alpha

C: remaining nucleons

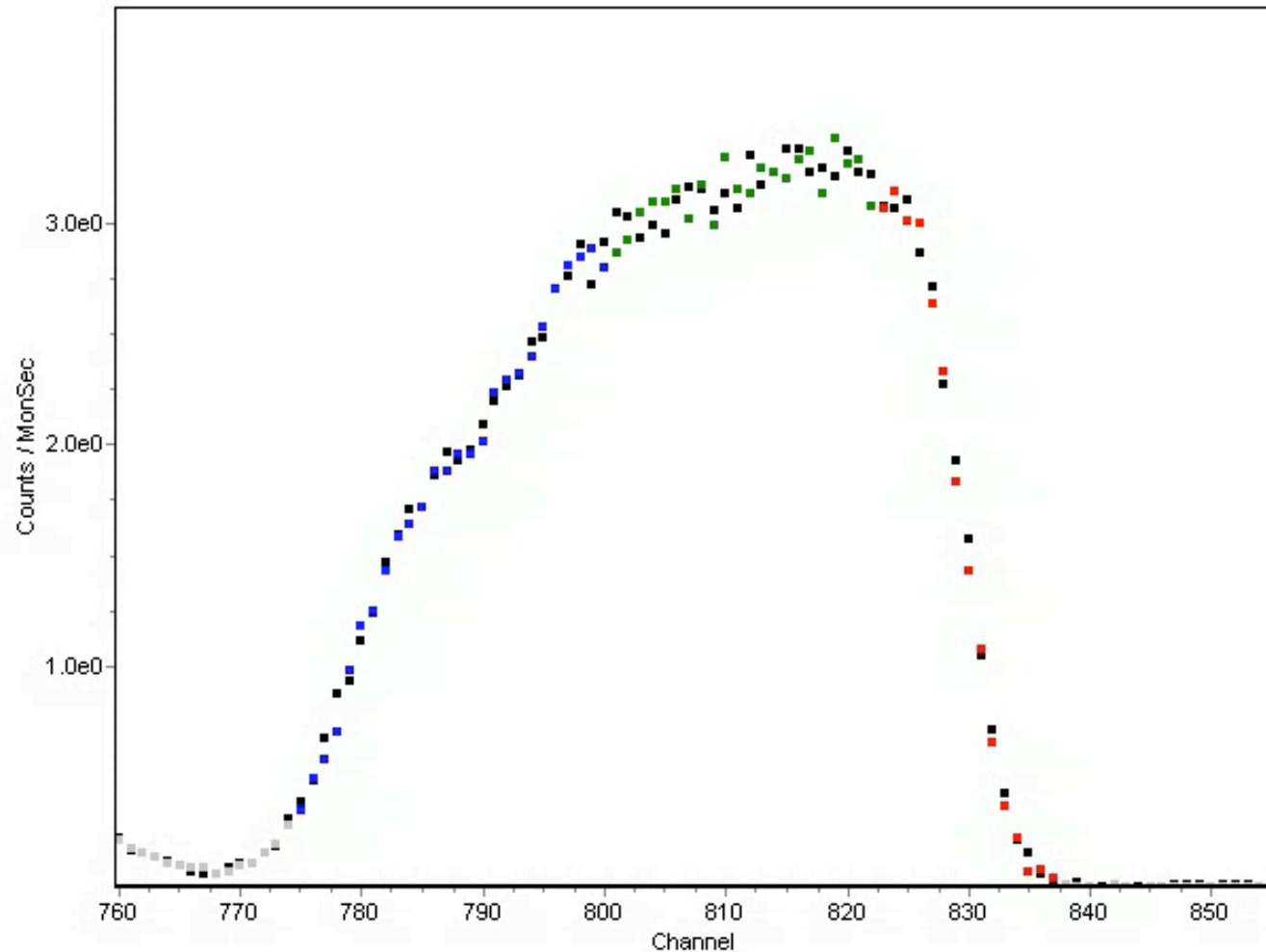
Q: kinetic energy (MeV)

An example:

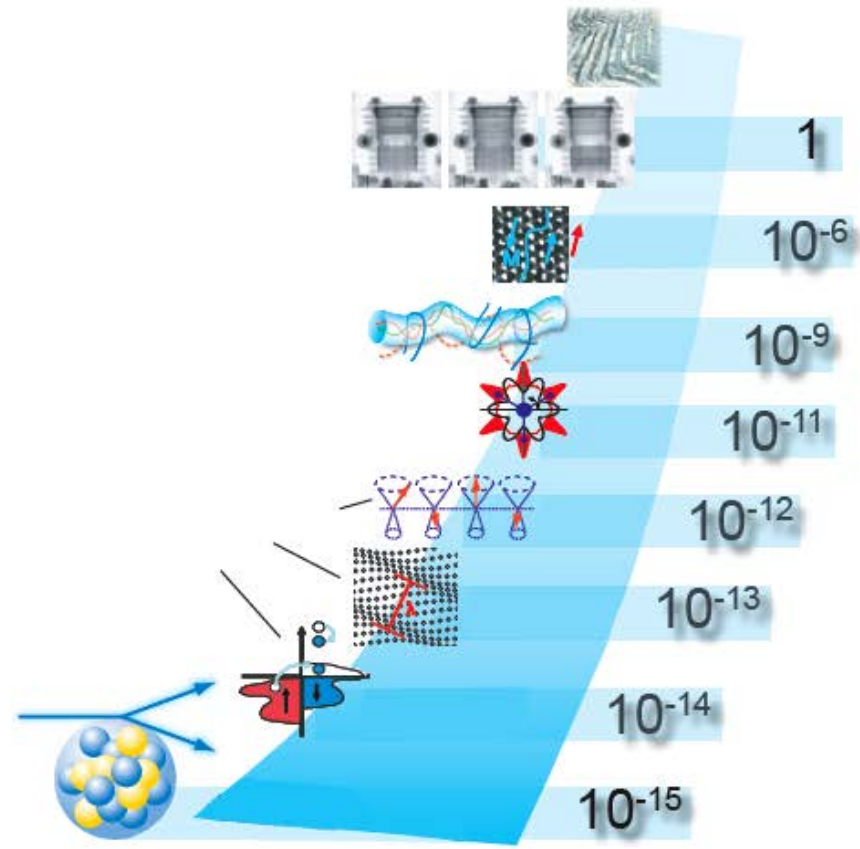
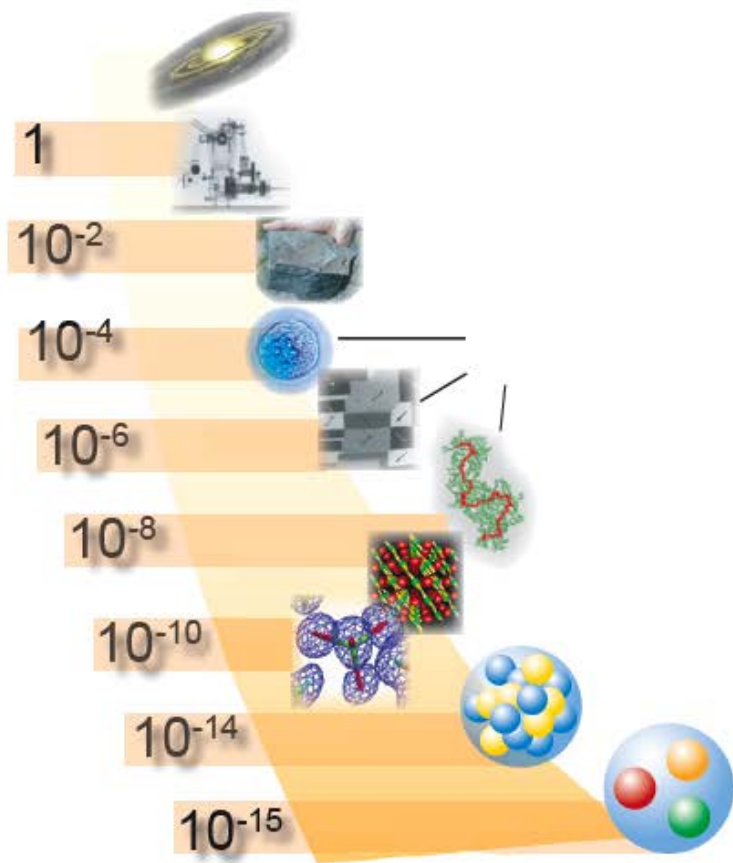




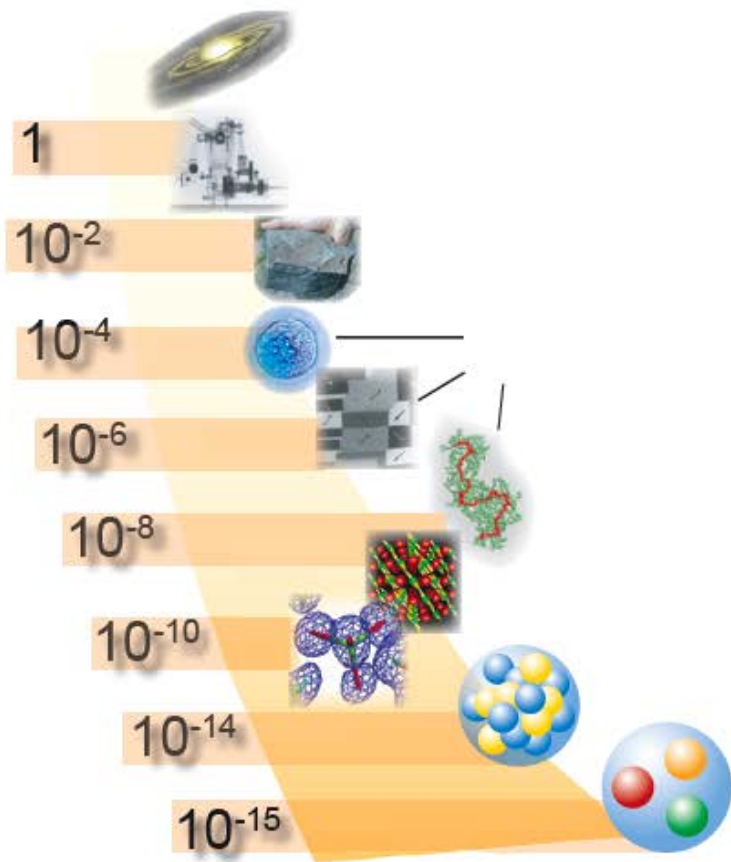
charging and discharging of a Li-ion battery



....and neutron scattering/imaging

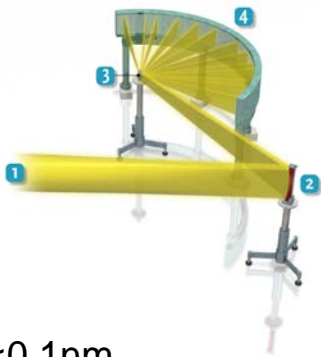


....and neutron scattering/imaging



PEARL

diffractometer



<0.1nm

0.01μm

0.1μm

1μm

0.01mm

>10cm

FISH

imaging/tomography

neutron
beam



ROG

reflectometer



SANS

small-angle scattering

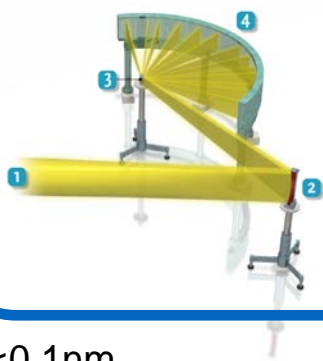


SESANS

L. van Eijck, L. et al. *J. Appl. Cryst.* 49, 1398–1401 (2016)

PEARL

diffractometer



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1 μ m

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FISH

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neutron
beam



ROG

reflectometer



SANS

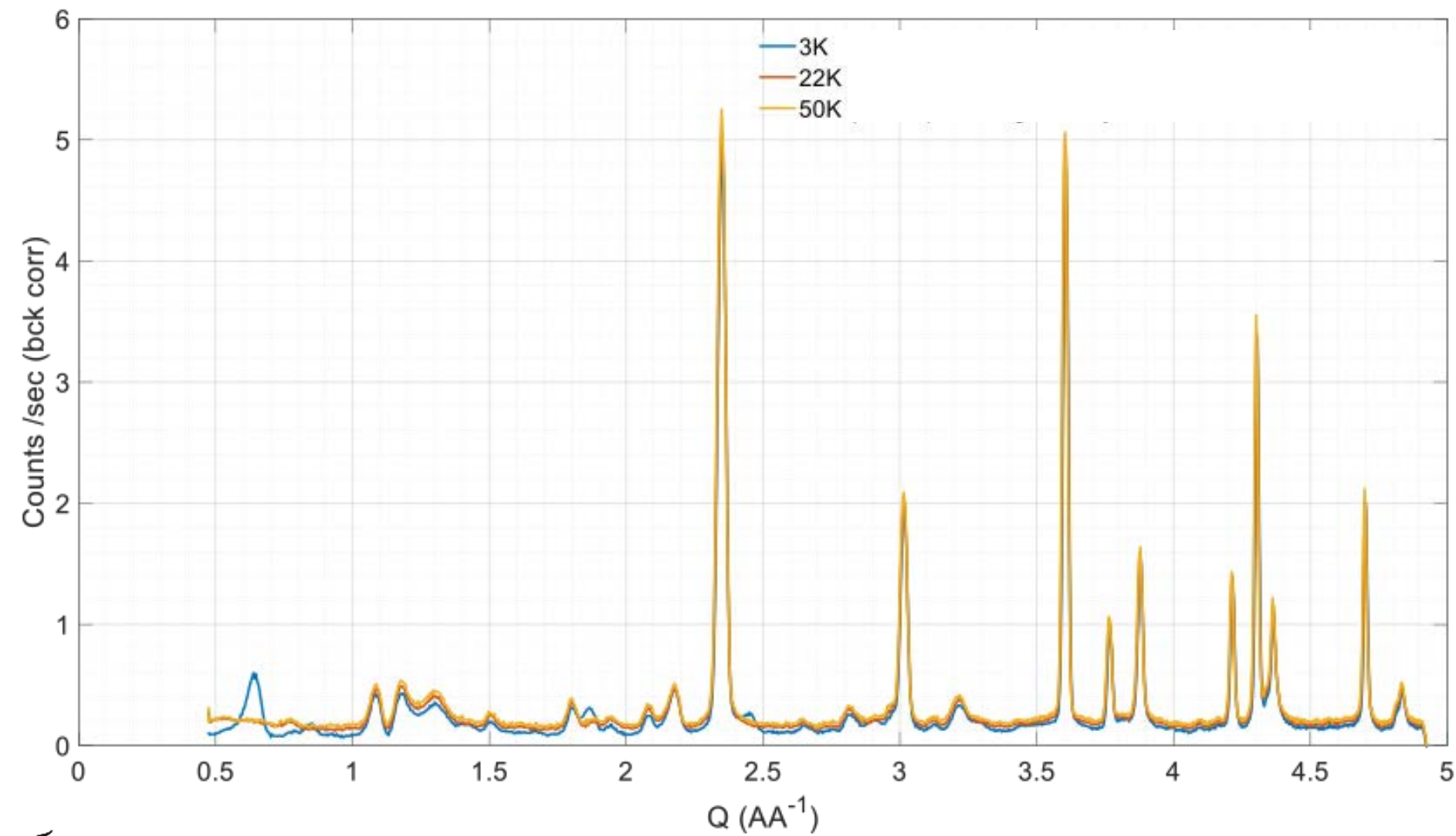
small-angle scattering



SESANS

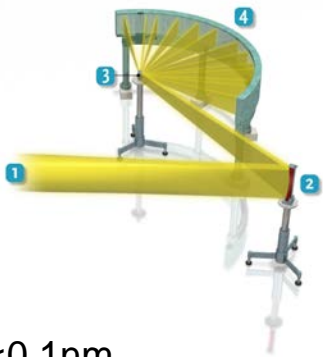


FeCl_3 $\lambda = 2.5 \text{ \AA}$



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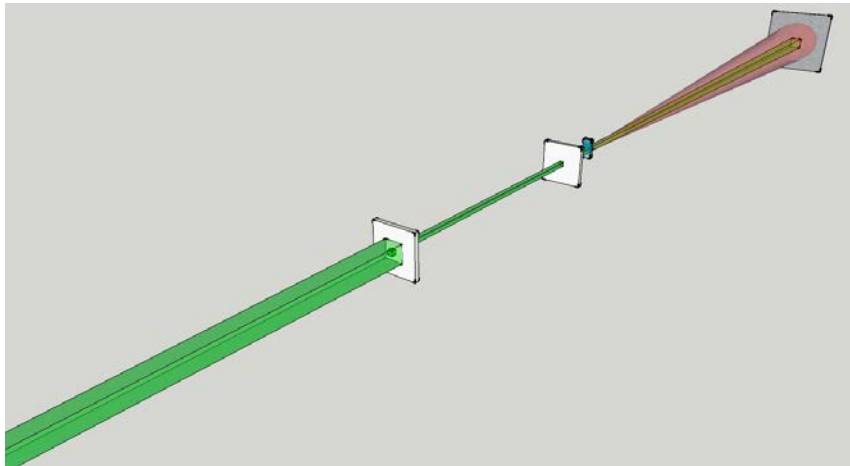


SESANS

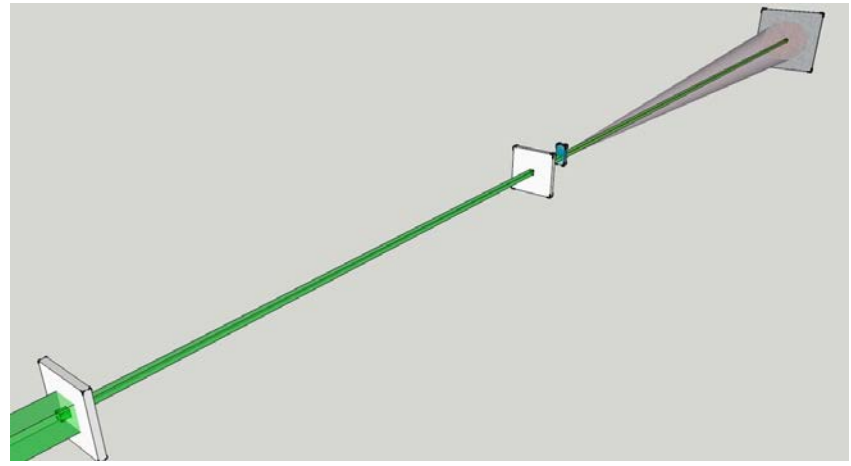
how to go beyond SANS to reach TEM or real space imaging resolutions ?

Problem...

intensity and resolution are in conflict

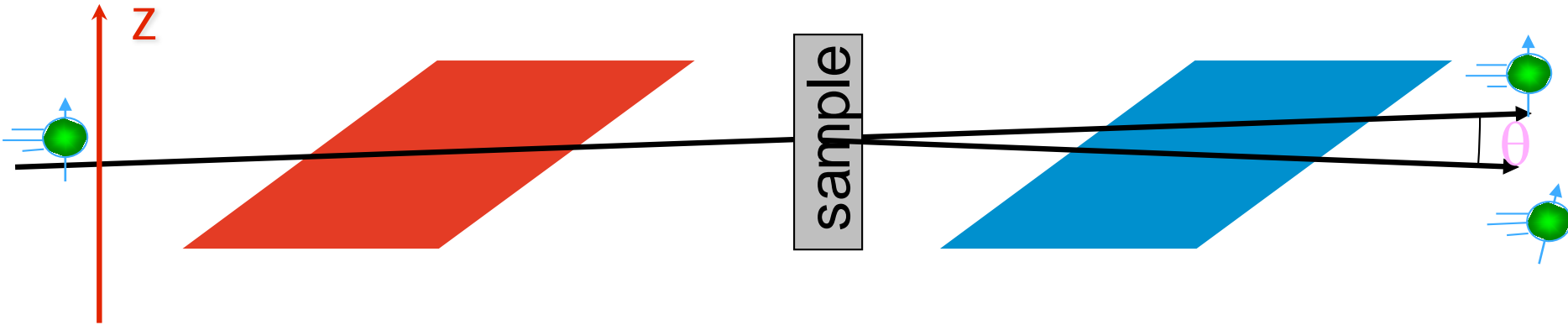


low resolution
high intensity



high resolution
low intensity

Realisation SESANS @ TUD

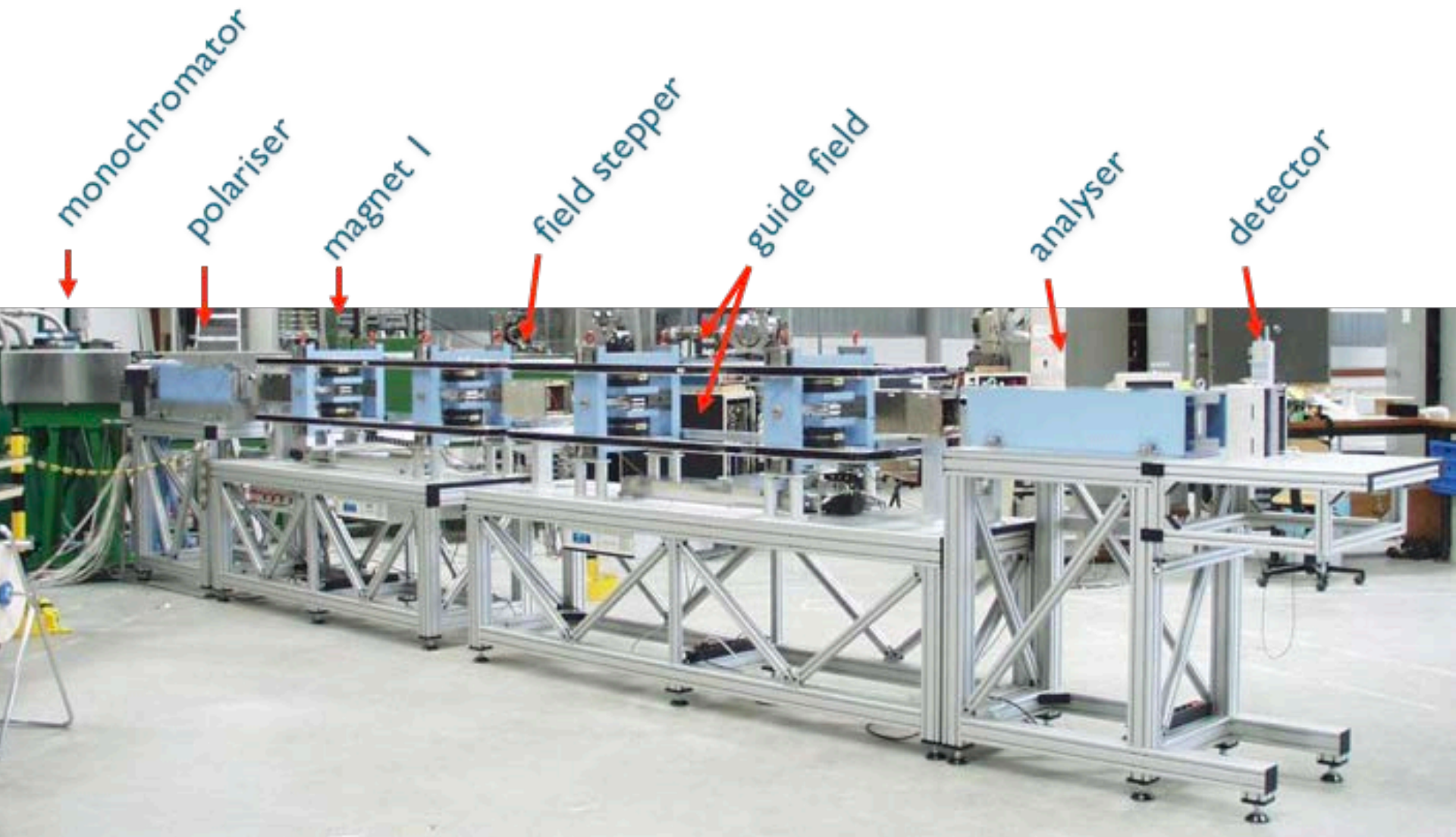


Non-scattered beam gives spin echo at $\phi = 0$
Independent of height and angle

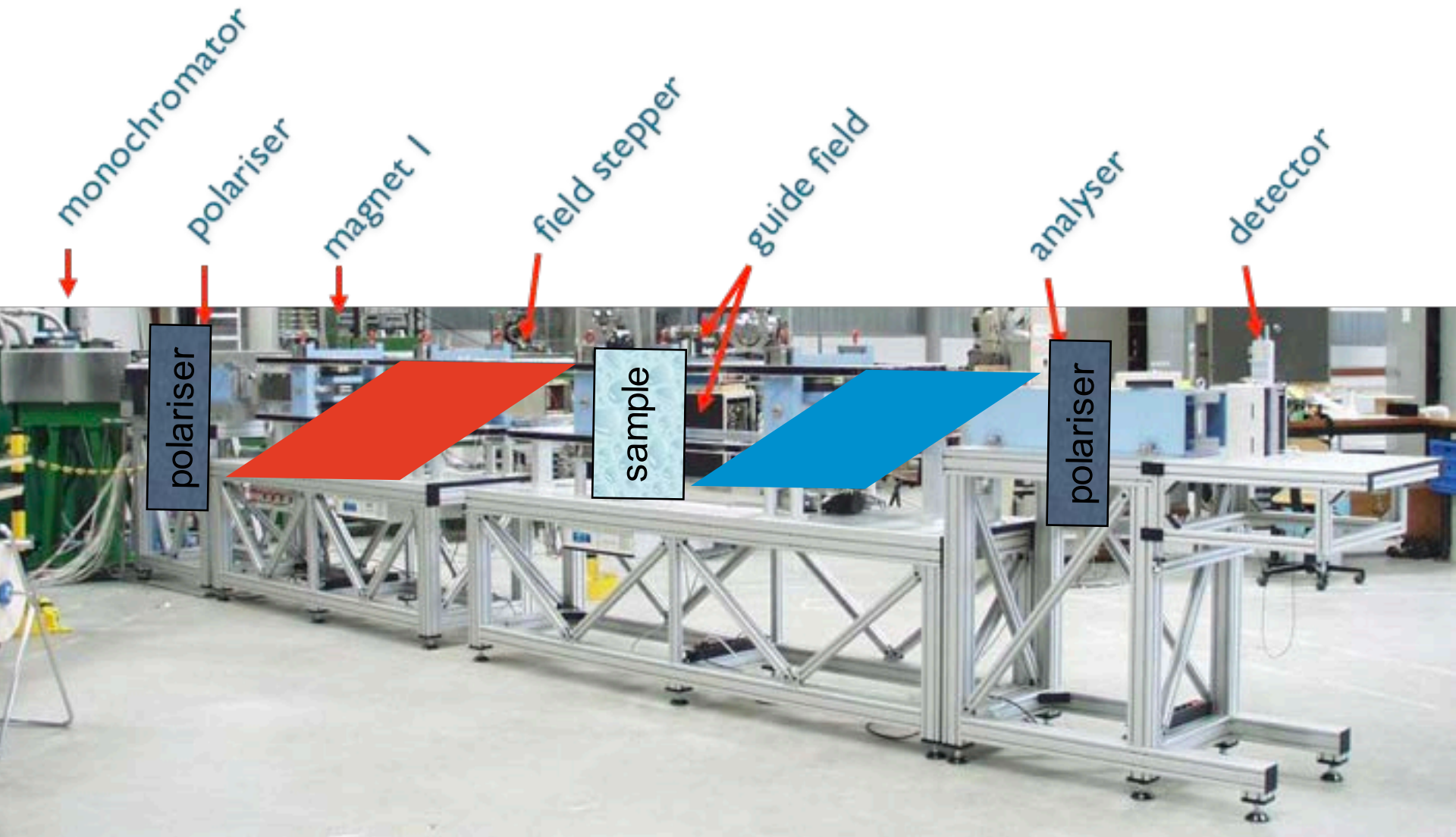
Scattered beam at Q_z results in precession $\phi \cong z Q_z$
Proportional to the **spin echo length** z and to Q_z

Measurement of the spin echo polarisation: $P(z) = \cos(z Q_z)$
gives the Fourier transform of $S(Q)$
which is the density correlation function $G(z)$

Realisation SESANS @ TUD



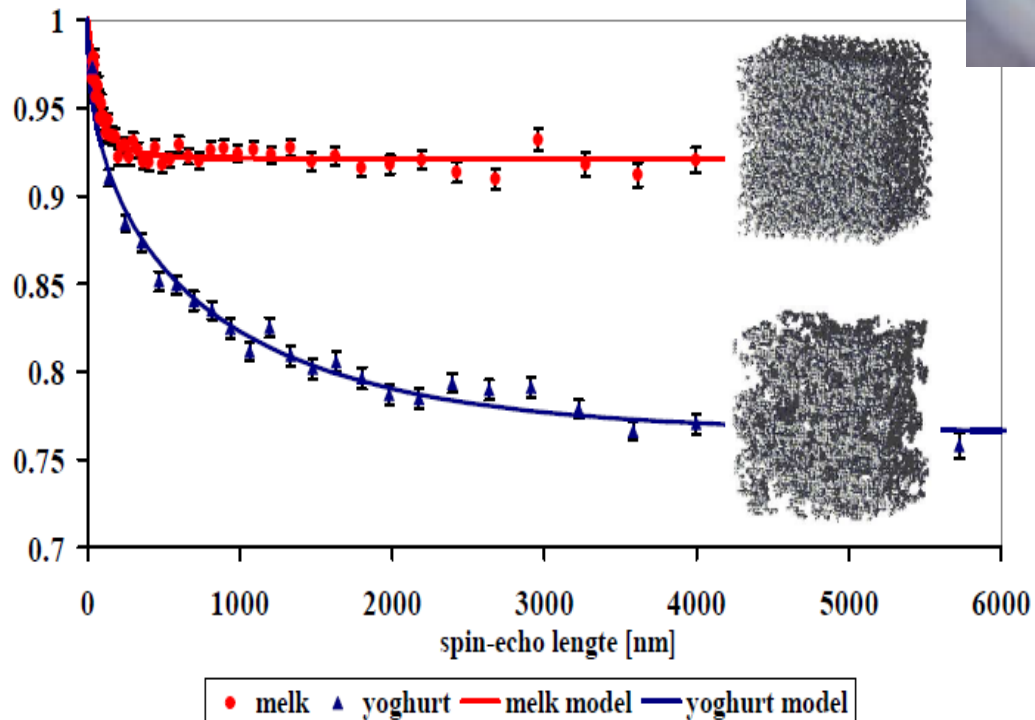
Realisation SESANS @ TUD



Applications of SESANS

spin echo lengths from 30 nm to 20 μm !

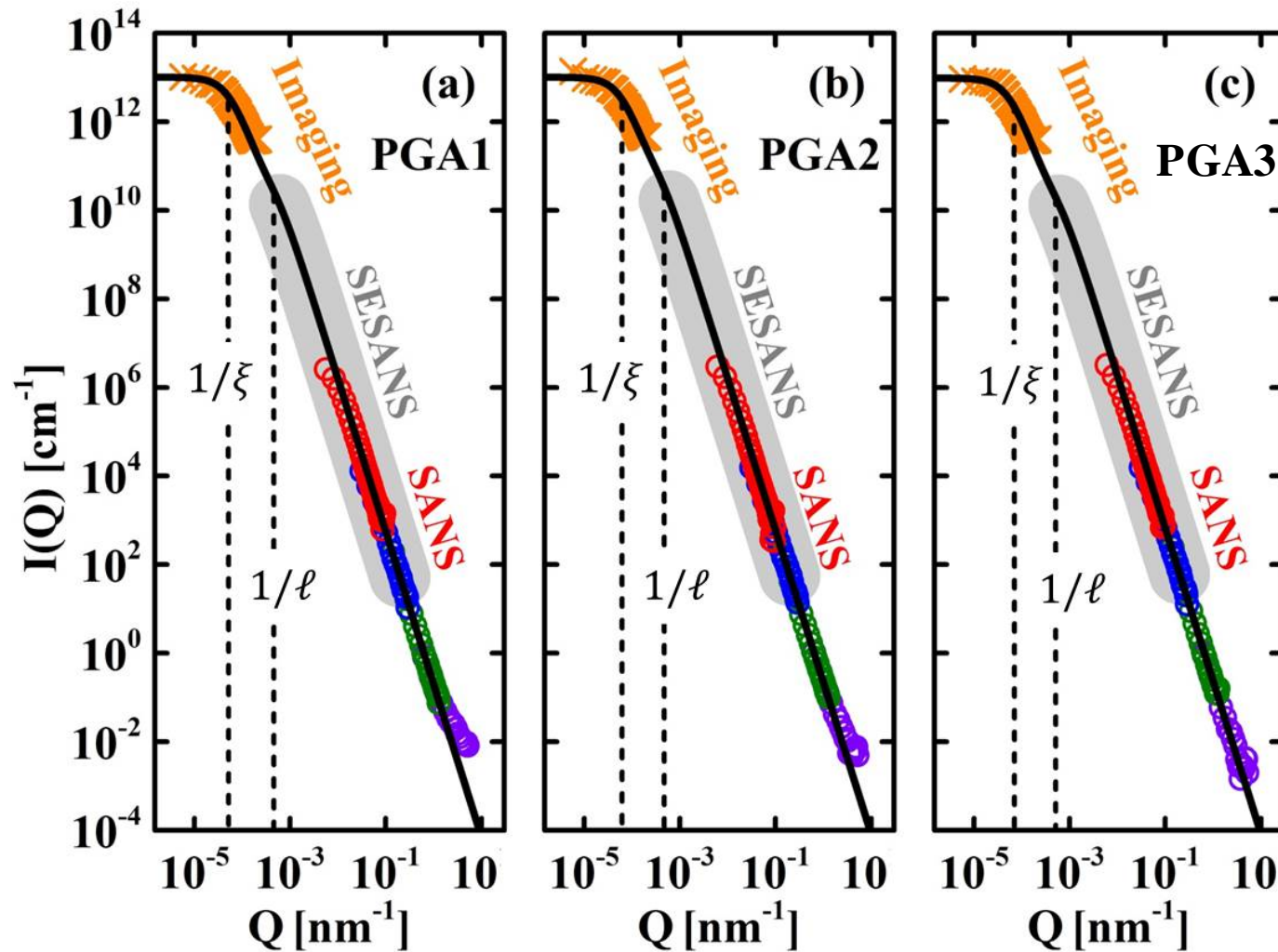
following how milk
becomes yoghurt



experiment
and
theory

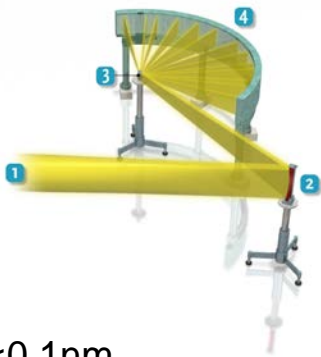
Structural information over 6 orders of magnitude in Q .

Combination of SANS, SESANS and real space imaging data:
the case of graphite



PEARL

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0.01mm

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FISH

imaging/tomography

neutron
beam



ROG

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SANS

small-angle scattering



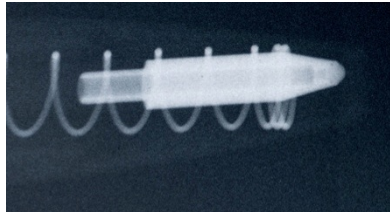
SESANS

First imaging experiments at TU Delft with a high resolution Medipix detector (Jeroen Plomp and Josef Uher)

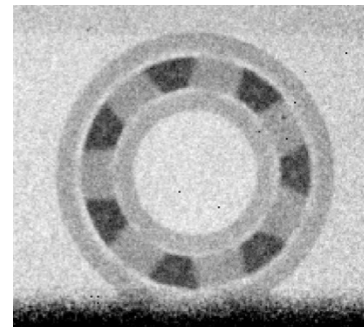
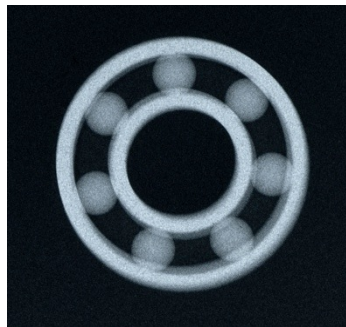
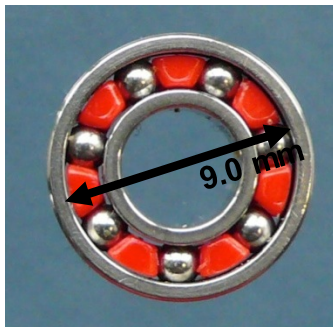
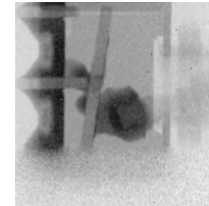
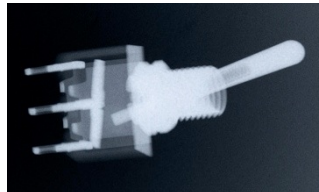
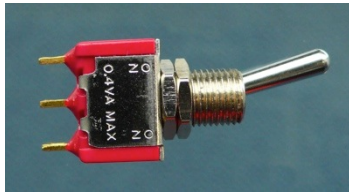
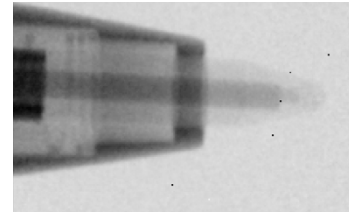
Visible light



X-rays



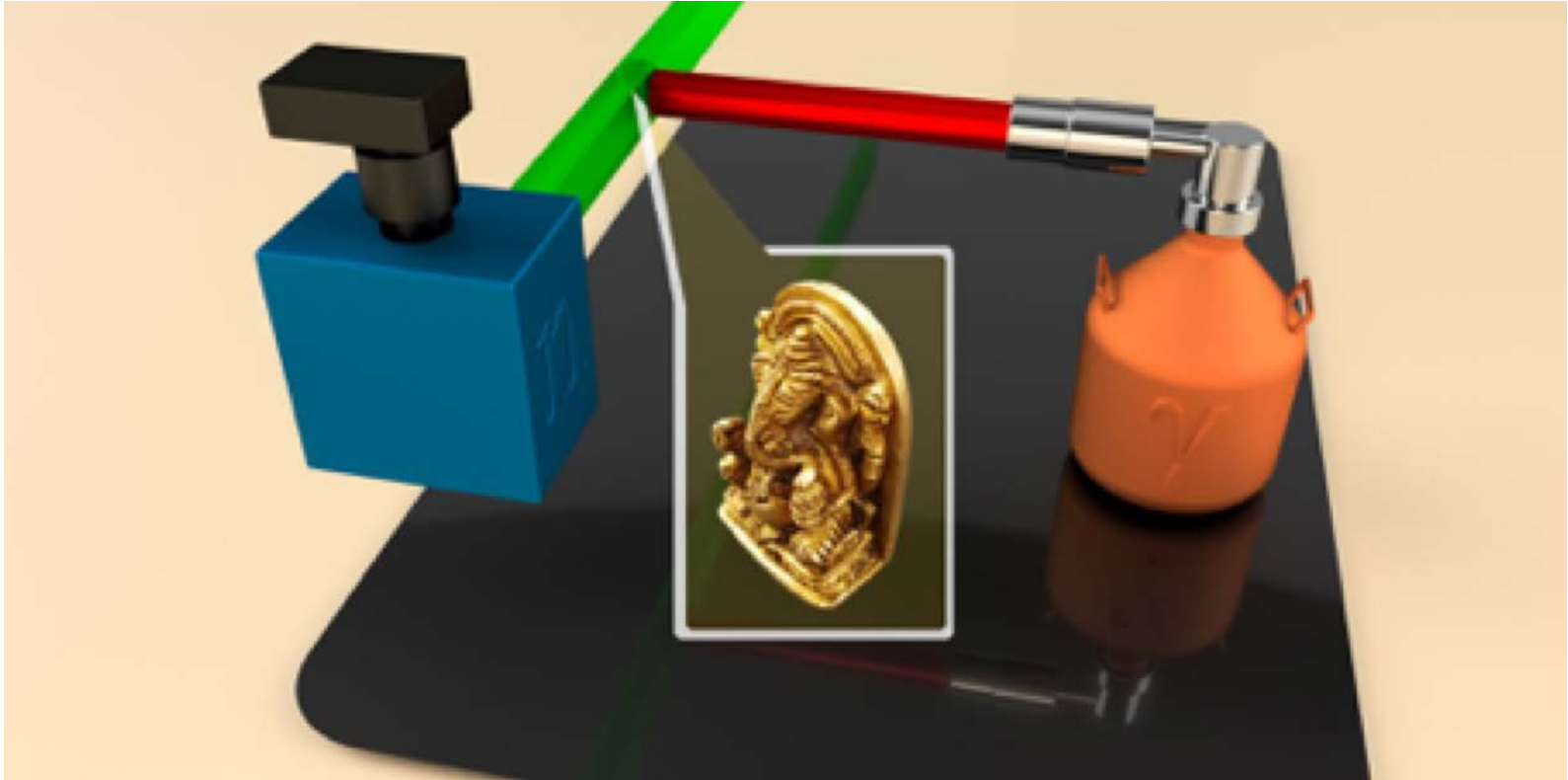
Neutrons



<http://www.youtube.com/watch?v=XK-woJToZ4Q>



The next step:
merging data from neutrons, X-rays and gammas
(prompt and delayed)



collaboration with the Rijksmuseum
funded by the Dutch Science Foundation

Mystery of Superior Leeuwenhoek Microscope Solved After 350 Years

