Neutron and **X-ray Scattering** of **Quantum Materials**

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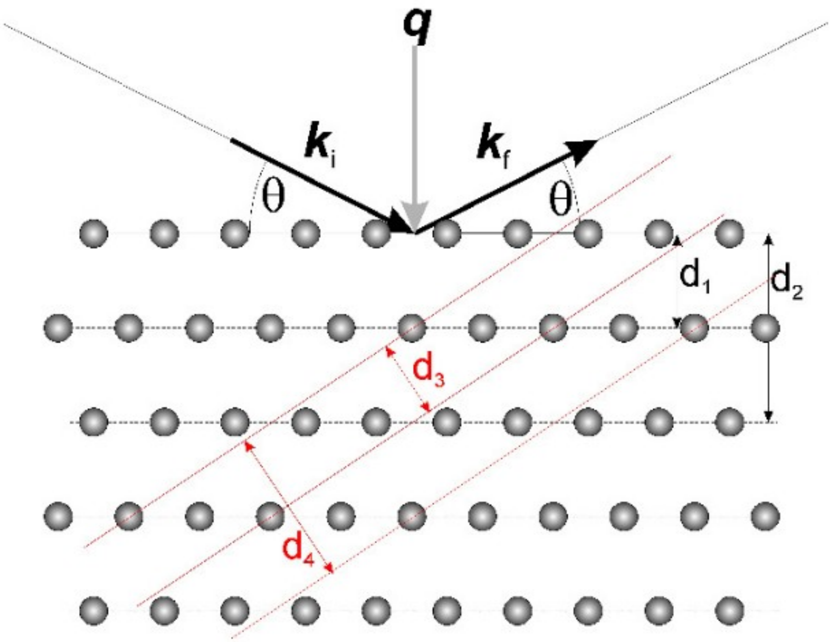
Outline for today

- Recap from last week (Chapters 9-10, except 9.1.5-8)
- Diffraction from magnetic structures
- Neutron instrumentation
  - Neutron guides
  - Monochromators and analyzers
  - Choppers and time-of-flight
  - Collimators and slits
  - Filters and velocity selectors
  - Detectors and monitors
  - Shielding and radiation safety

From last week: Neutron diffraction

Differential cross section for diffraction on a crystal:

$$\frac{d\sigma}{d\Omega} = N\frac{(2\pi)^3}{V_0}e^{-2W}|F_N(q)^2|\sum_\tau \delta(q-\tau)$$



The nuclear structure factor:

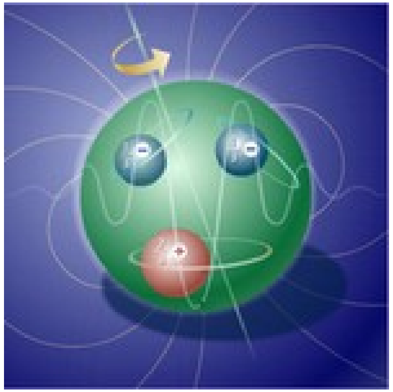
$$F_N(q) = \sum_n b_n e^{i(q\cdot\Delta_n)}$$

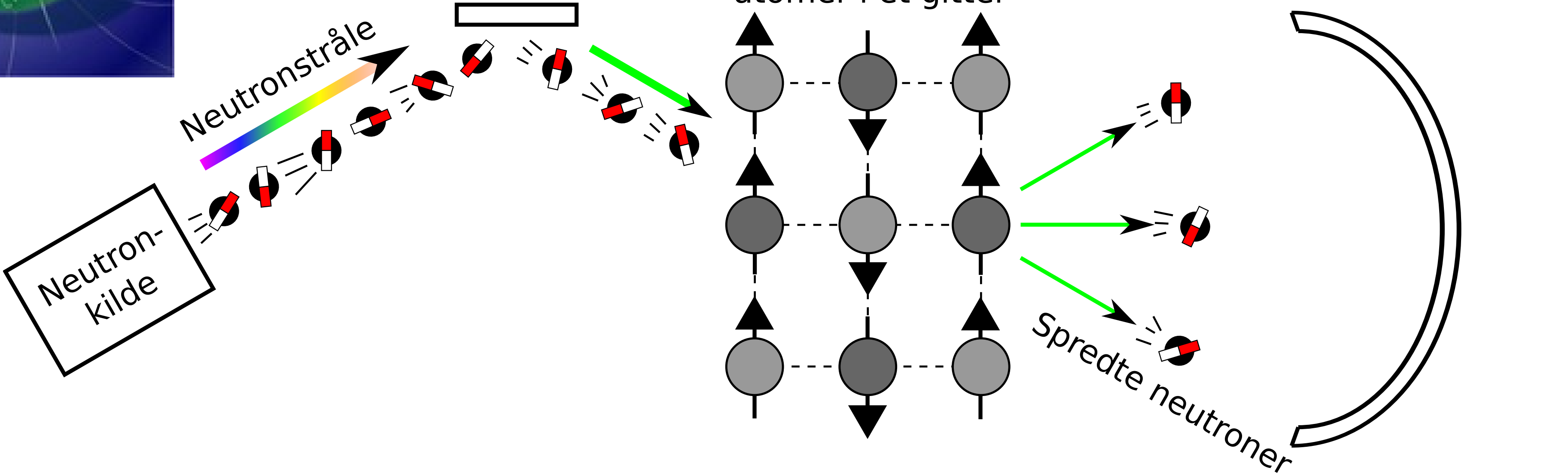
The Laue condition and Bragg's law

$$q = \tau \qquad\qquad n\lambda = 2d\sin(\theta)$$

Diffraction from magnetic structures

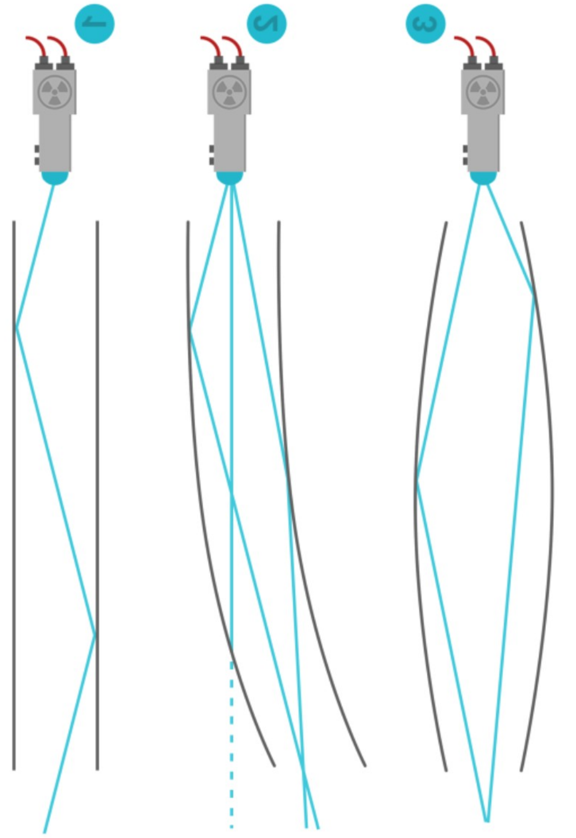
The neutron magnetic dipole moment



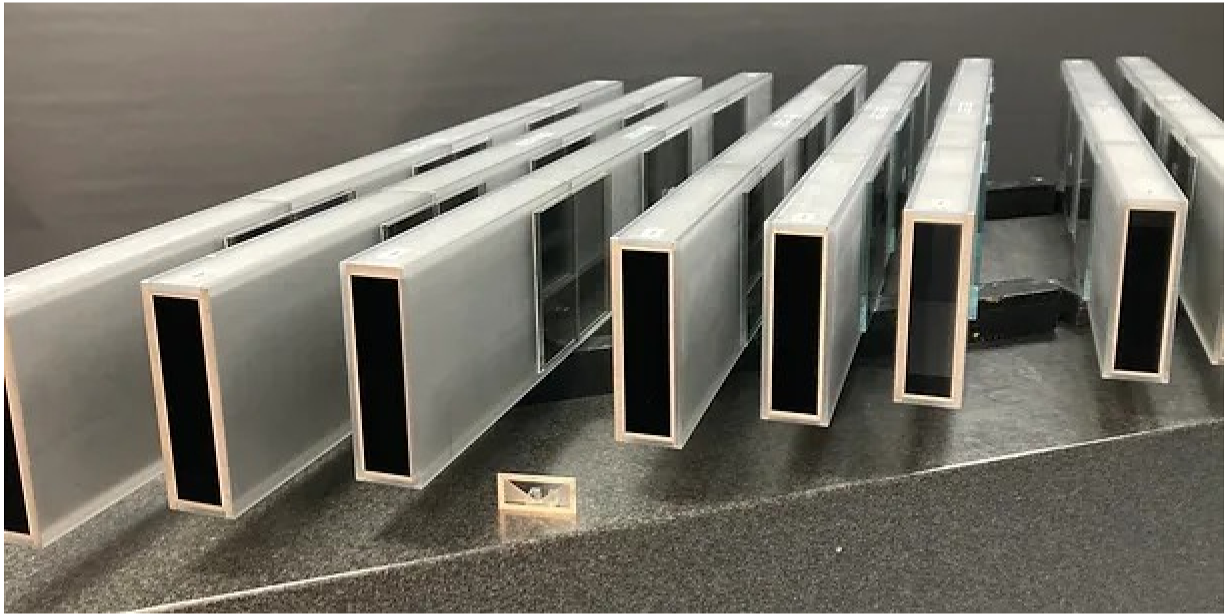


Neutron instrumentation

Neutron guides

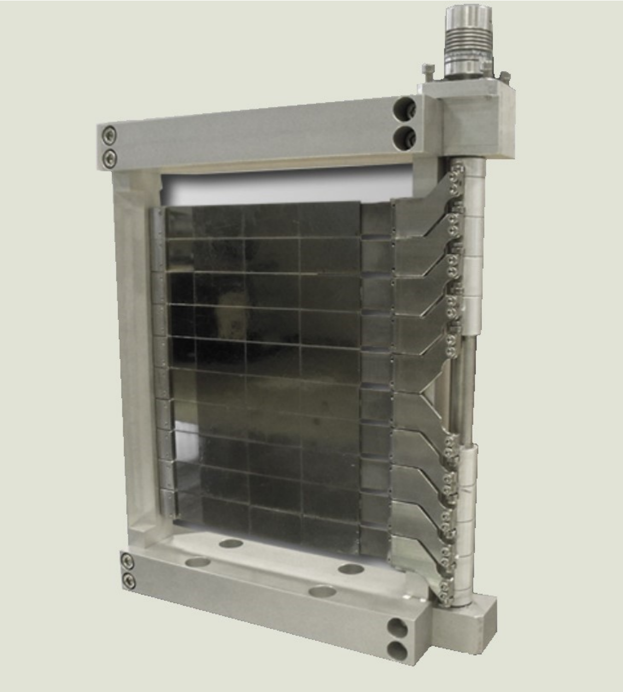


ILL, 240x60 mm, m = 3

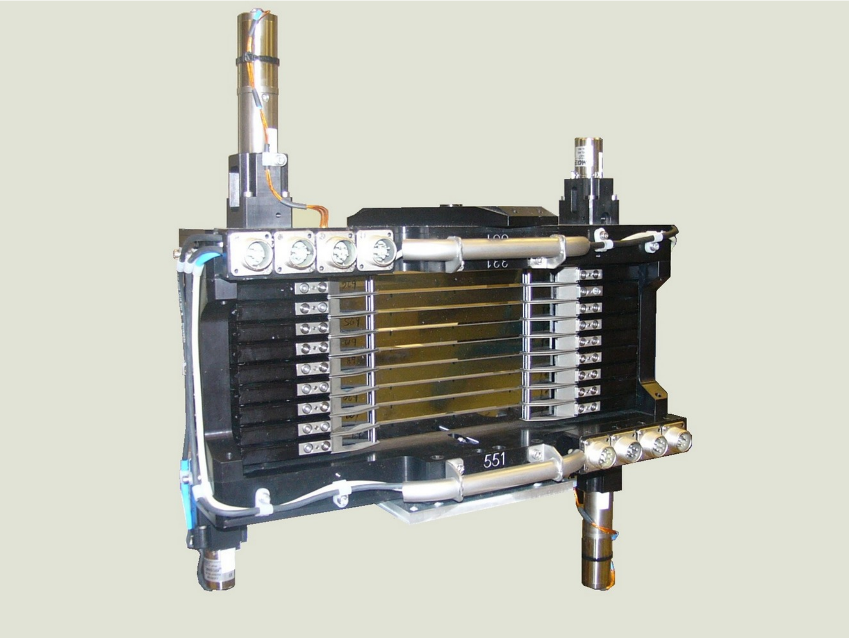


Monochromators and analyzers

Vertical focusing PG monochromator

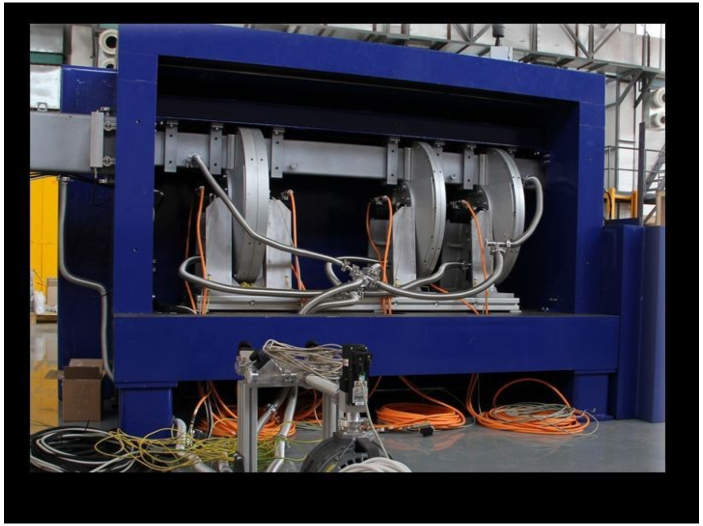


Double focusing Si monochromator



Monochromating using choppers

Disc chopper



Chopper housing

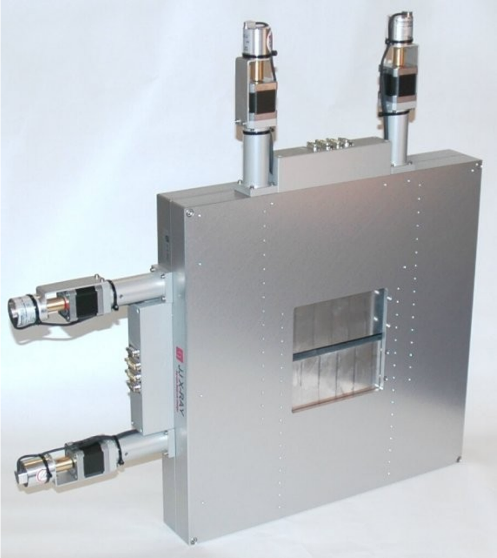
Fermi choppers

Collimators and slits

Soller collimator

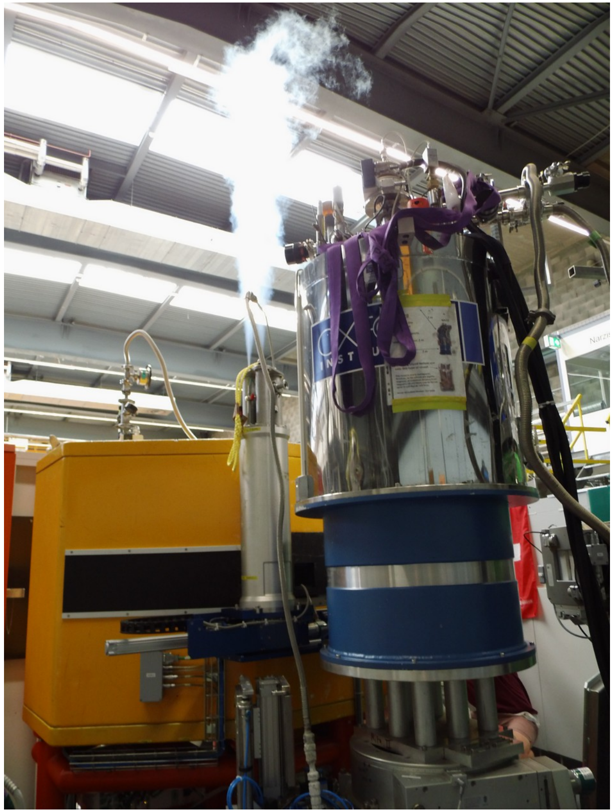
Radial collimator

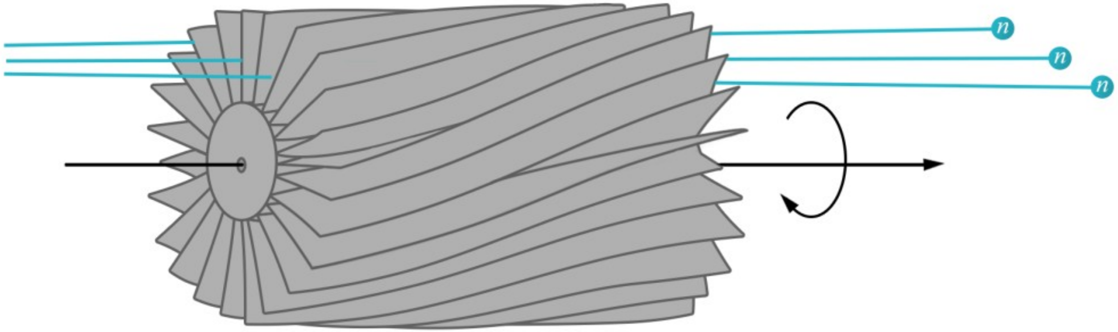
Motorised slits

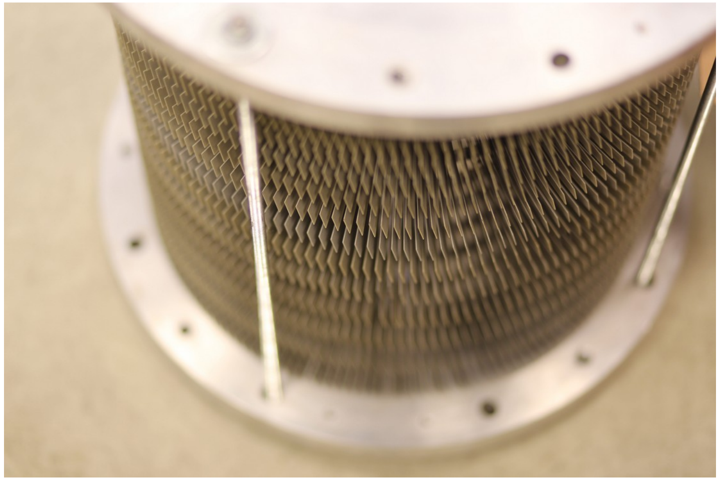


Circular diaphragms

Filters and velocity selectors



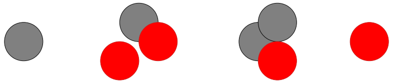




Detectors and monitors

- Neutrons cannot be directly detected
- They need to be converted to charged particles
- Monitors are just inefficient detectors

$$n + {}^{3}He \rightarrow {}^{3}H + p + 765\ \text{keV}$$



$$n + {}^{10}B \rightarrow \begin{cases} {}^{4}He + {}^{7}Li + 2310\ \text{keV}\ (94\%) \\ {}^{4}He + {}^{7}Li + 2792\ \text{keV}\ (6\%) \end{cases}$$

BASIS at SNS

Shielding

Shielding serves several purposes:

- Get rid of unwanted neutrons on the sample position and detector
- Avoid activating sample environment etc. unnecessarily
- Keep radiation levels at working areas within safe limits

For neutrons

Cadmium

Gadolinium paint

Boron carbide

Borated polyethylene

For gammas, betas and X-rays

Dense concrete

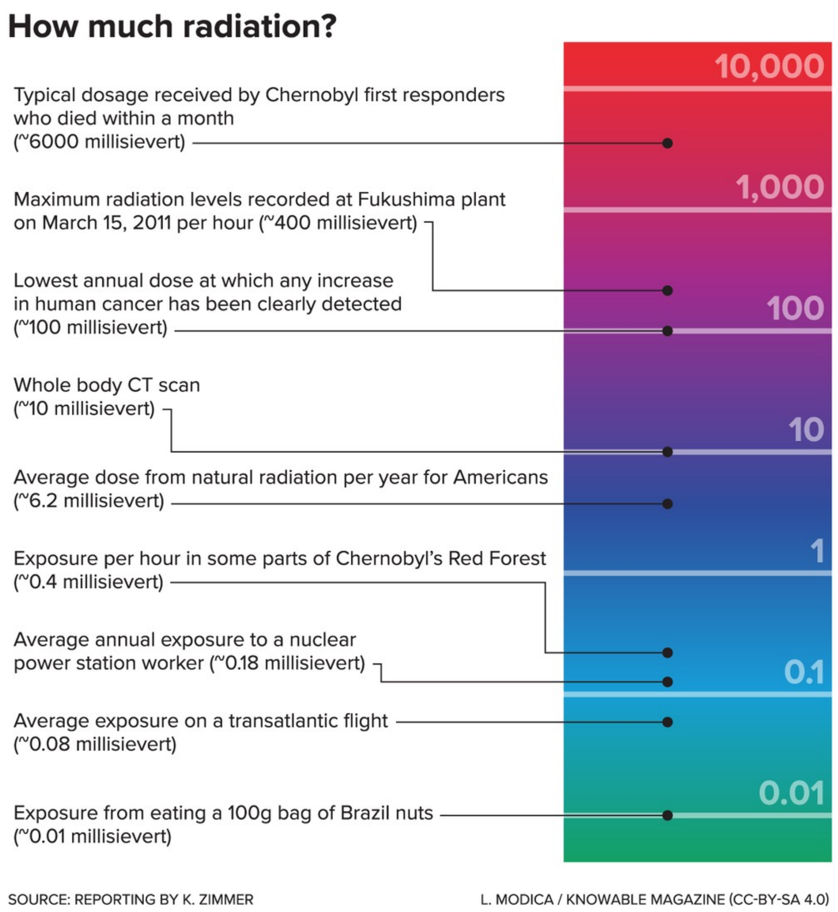
Lead

Acrylic

Radiation safety on a neutron beamline

Radiation protection measures:

- Keep radiation levels at working areas within safe limits (shielding) and limit exposure time
- Radiation meters are used before entering experimental areas
- Dosimeters
- Hand and foot monitors

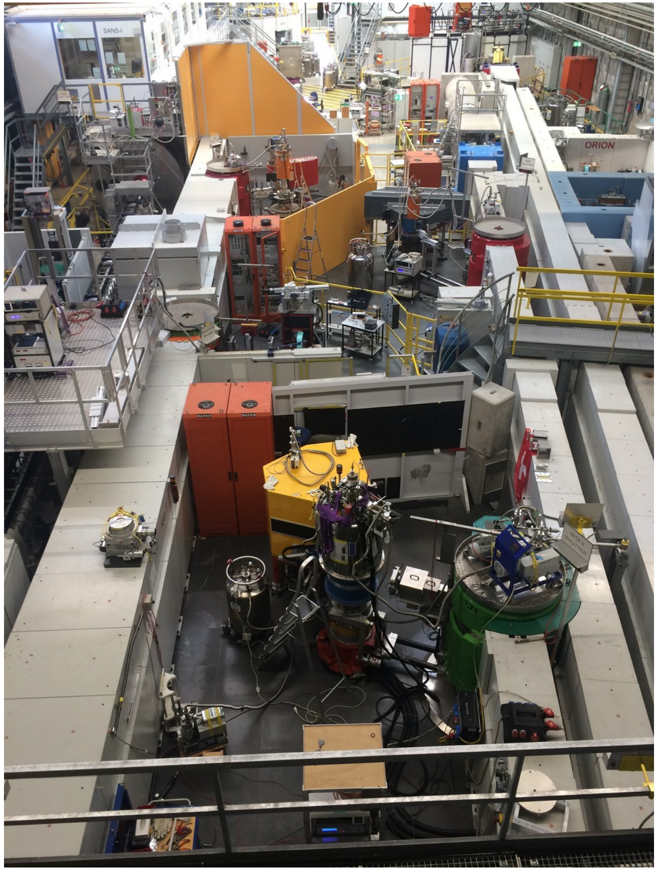


Virtual experiments

Ray tracing to simulate a neutron experiment

- Perform all the scans that one would do on a real experiment
  - Sample rotation, a3
  - Slits, before and after the sample
  - Scattering angle, a4
  - Along some direction in q
  - Energy, either ki or kf
- Useful for:
  - Design of new instruments or new parts for existing instruments
  - Optimize instrument configurations for an experiment, either before or during
  - Investigate whether measured feature could come from the instrument

Performing a diffraction experiment at RITA-II



McStas exercise

Install McStas from www.mcstas.org (if you haven't already)

The creator of today's exercise:

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Niels Bohr Institute
University of Copenhagen