Scattering experiments with q and E resolution

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with special thanks to Helmut Schober

Scattering experiments with q and E resolution

Thermal neutrons around:

$$E \; = \; k_B T\,(300\text{K}) \; = \; 25\text{ meV} \quad (\lambda = 1.8\text{ Å})$$

Very useful and handy for neutrons:

$$E \approx 2\,k^2 \;(E \text{ in meV}, k \text{ in Å})$$

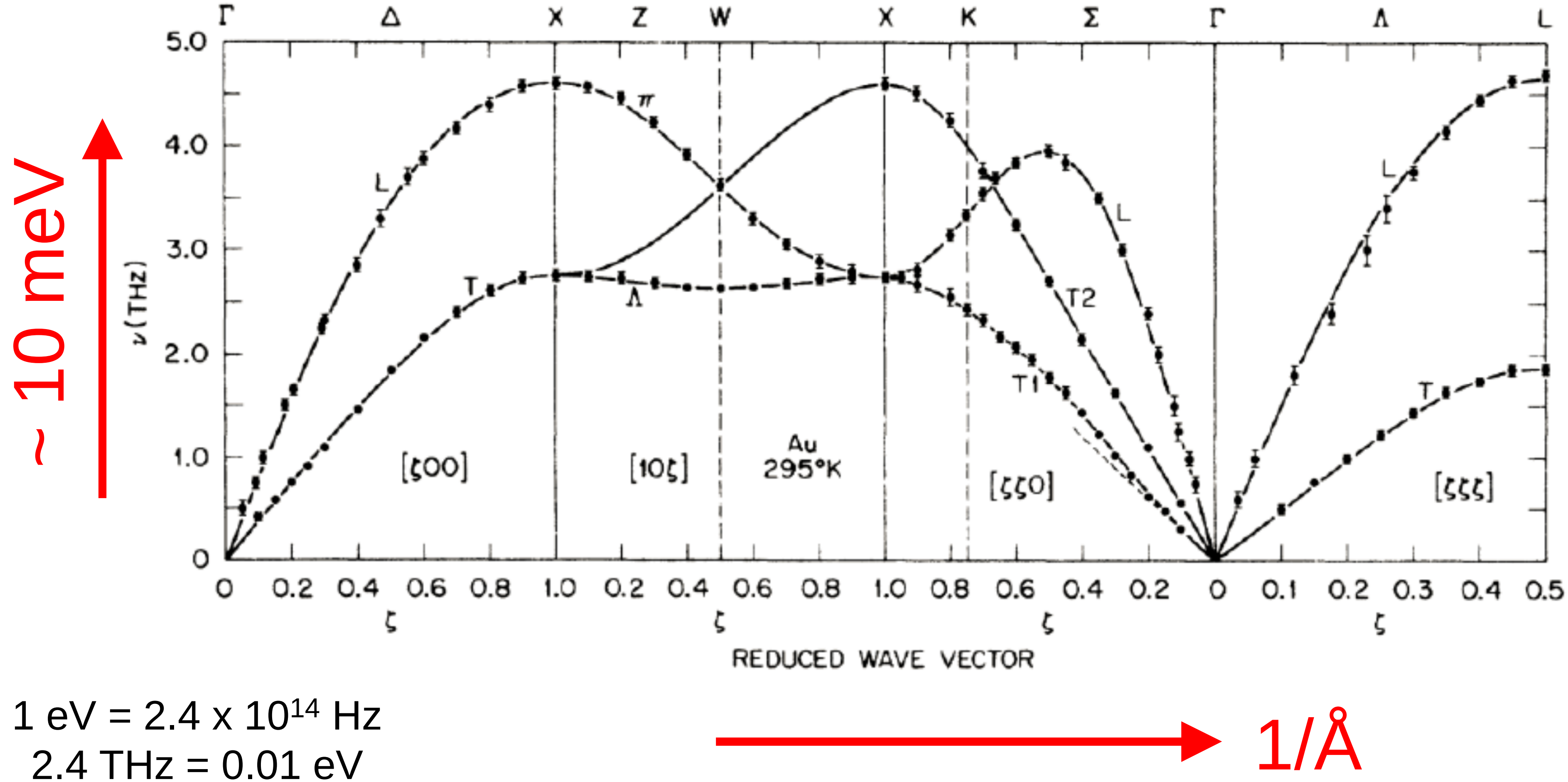
More precisely:

$$E = \frac{\hbar^2 k^2}{2m} = \frac{82\text{ meV}}{\lambda^2\left[\text{Å}^2\right]}$$ Energy

$$v = \frac{\hbar k}{m} = \frac{h}{m\lambda} = \frac{6.6261\cdot 10^{-34}\text{Js}}{1.6749\cdot 10^{-27}\text{kg}} = \frac{3956\,\frac{\text{m}}{\text{s}}}{\lambda[\text{Å}]}$$ Velocity

$$T = \frac{L}{v} = 252.77\mu\text{s}\cdot\lambda[\text{Å}]\cdot L[\text{m}]$$ Time of flight

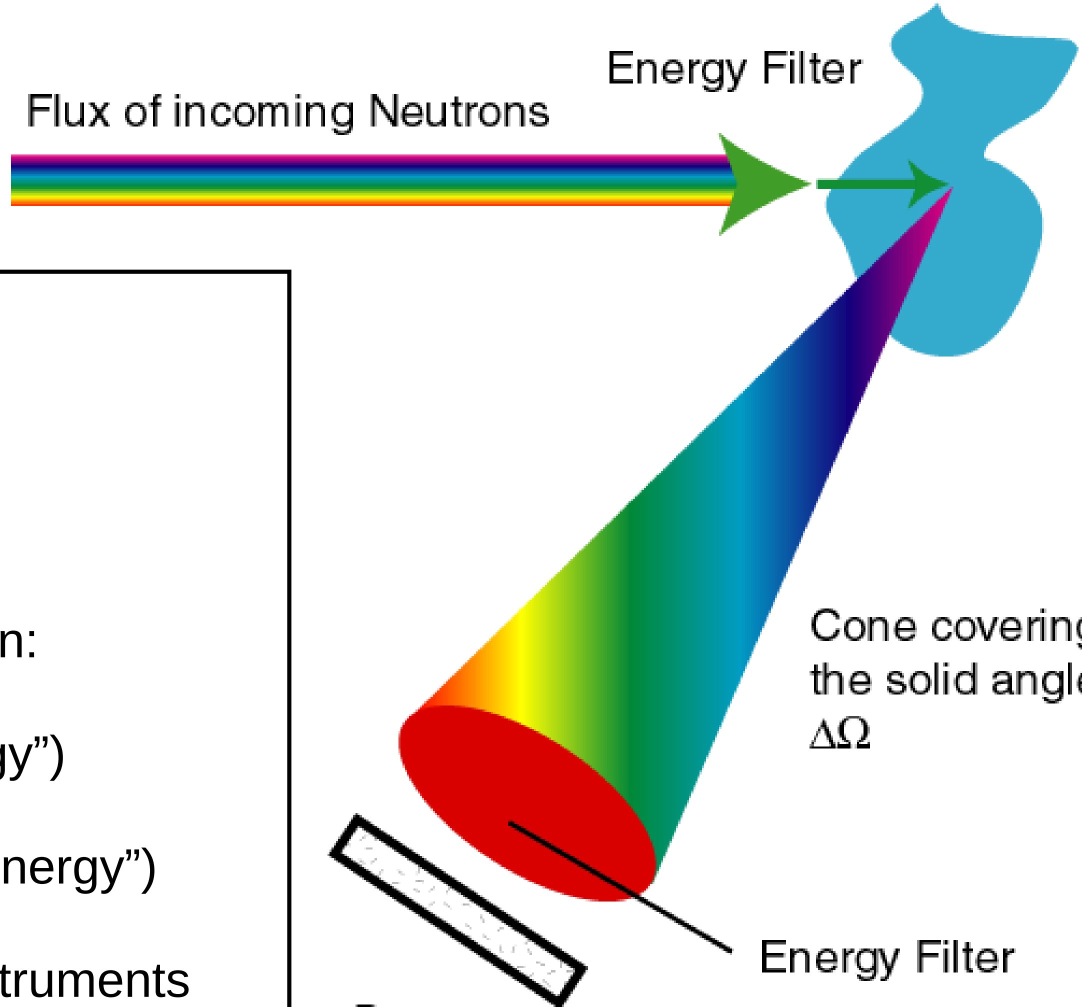
Phonon dispersion relation in gold



1 eV = 2.4 x 10^{14} Hz
2.4 THz = 0.01 eV

J. W. Lynn, H. G. Smith, and R. M. Nicklow, *Phys. Rev. B* **8**, 3493 (1973).

The scheme of a (any) scattering experiment



- Experimental information is contained
  in measured <u>intensities *I*</u>
  as a function of <u>angle (i.e. *q*)</u>
  and <u>energy (*E*)</u>

- Control parameters for energy resolution:

  1) Three-axis instruments ("Bragg energy")

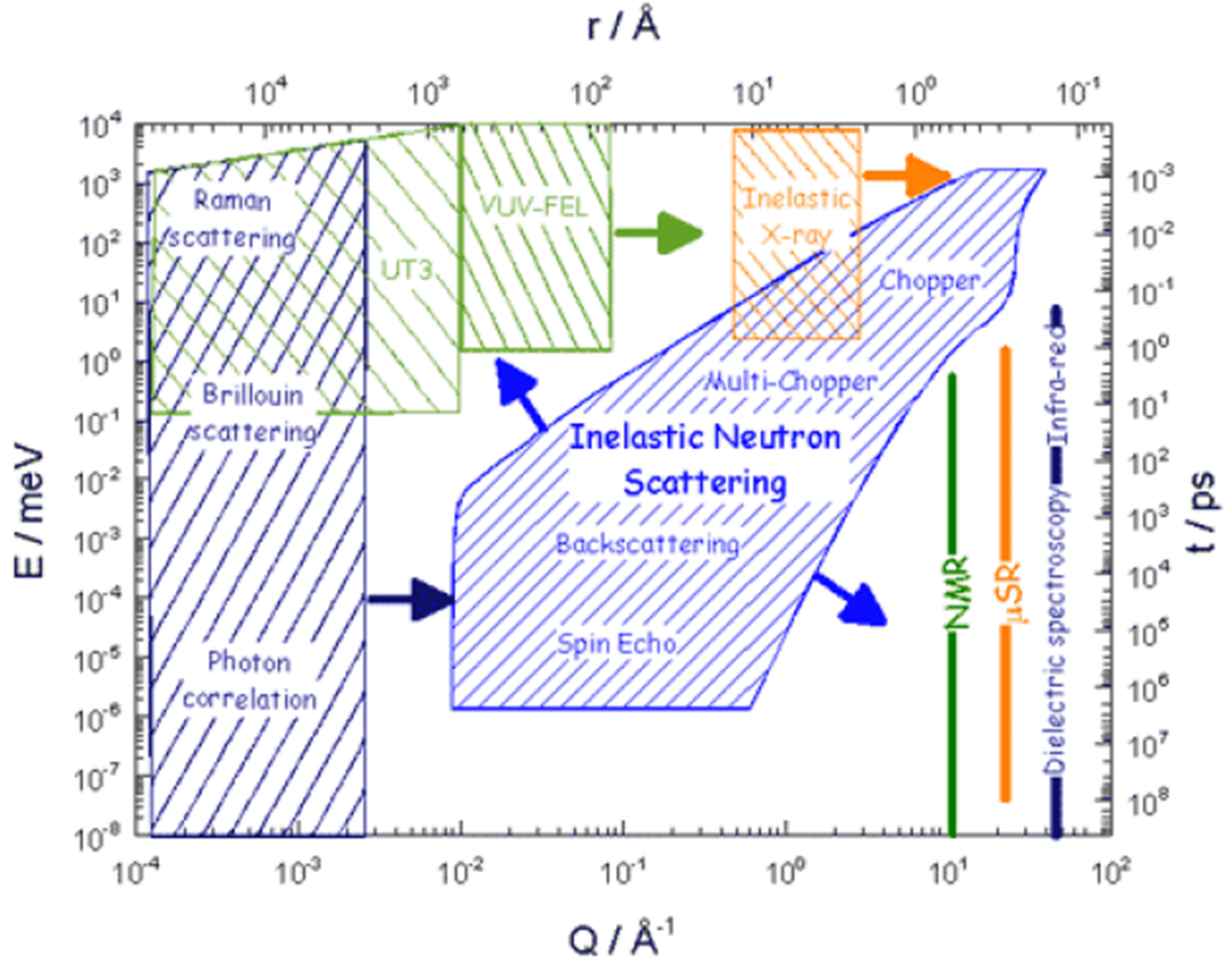
  2) Backscattering instruments ("Bragg energy")

  3) Time of detection for time-of-flight instruments

  4) Magnetic field B for spin-echo ("precession")

- Polarization resolution (magnetism)

Complementarity of techniques as seen in the reciprocal space



Source : http://www.ess-europe.de/en/data_images/N-complementarity.gif

1 meV = 11°K

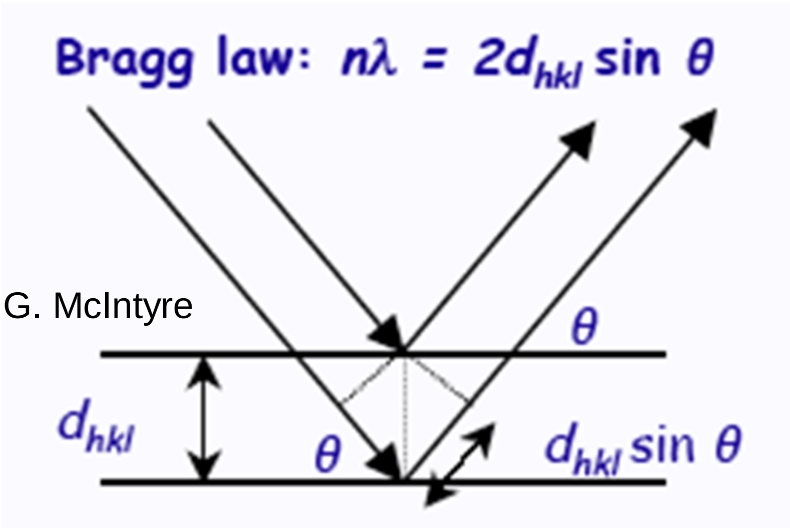
1) Three-axis spectrometer

Principle:

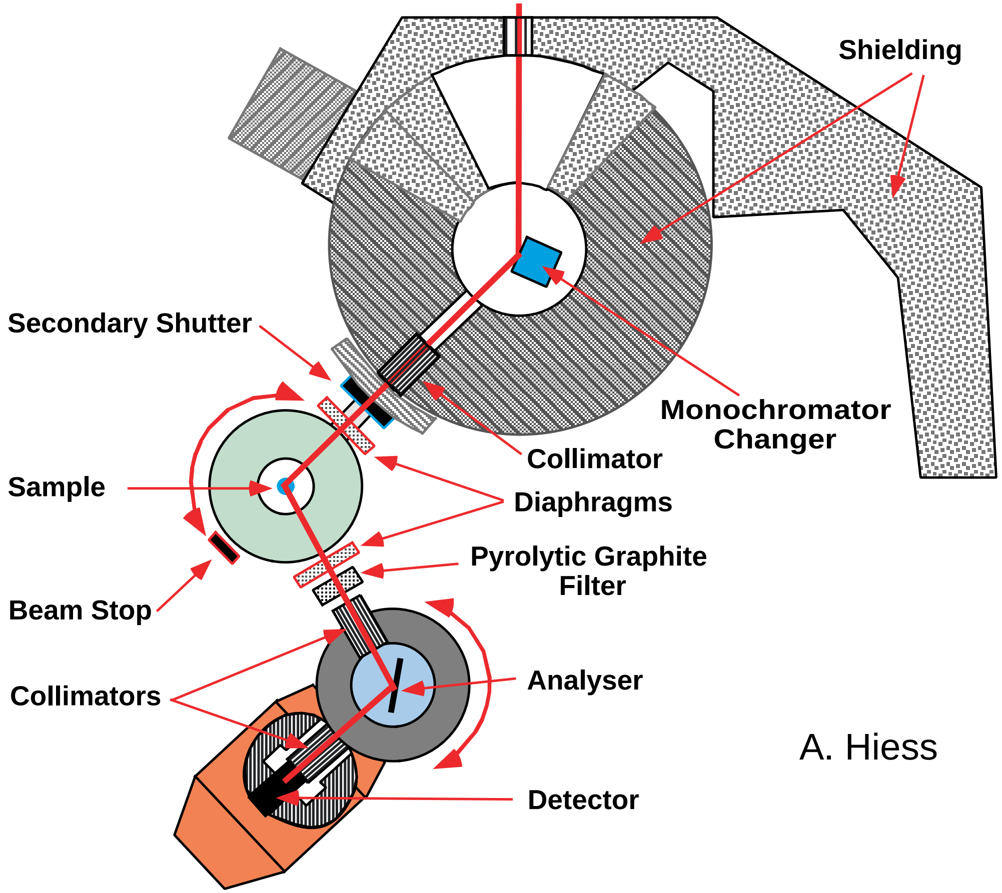
Energy selection via Bragg reflection from (monochromator) crystal

Three-axis spectrometer

The father of all continuous wave instruments



G. McIntyre



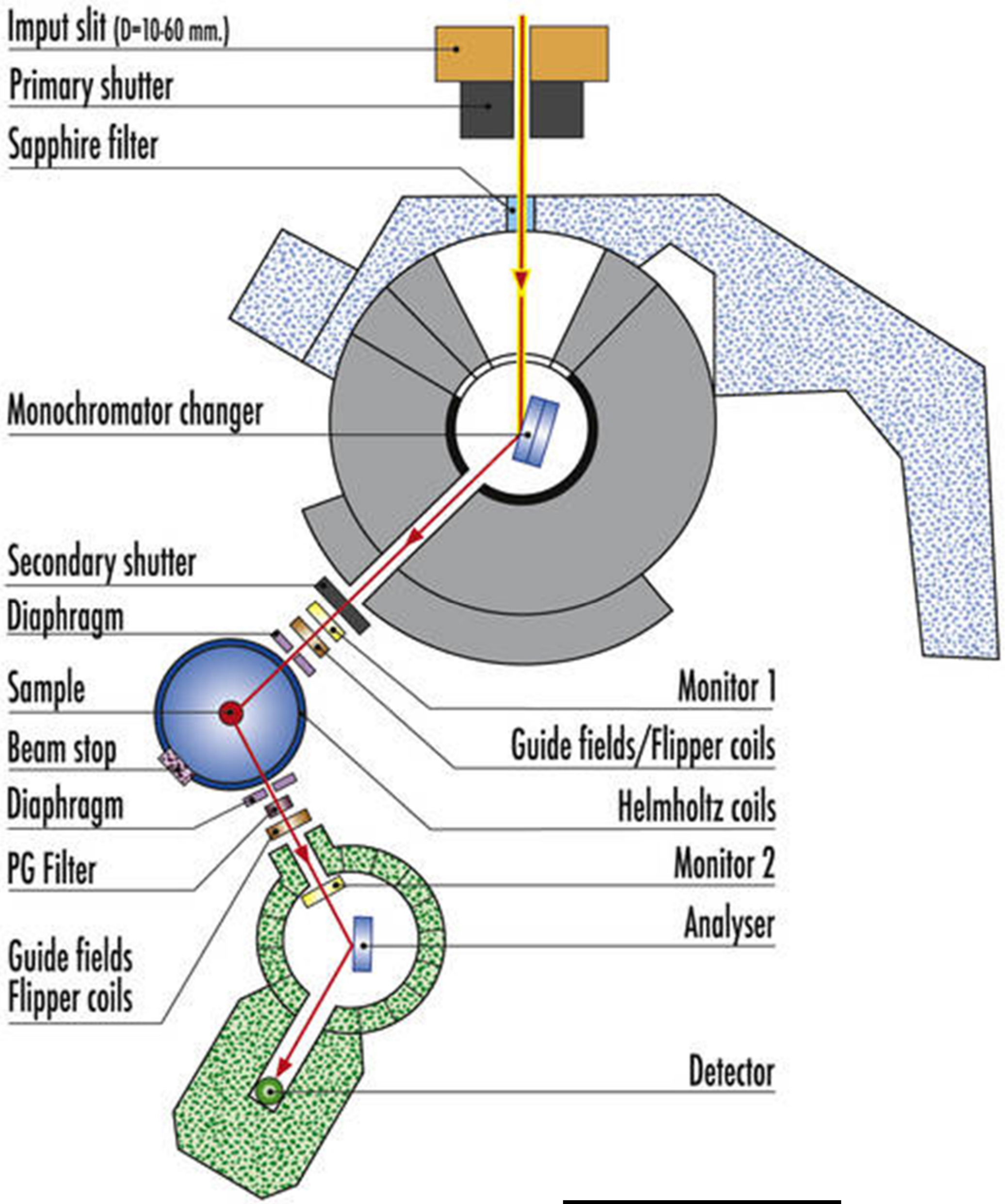
A. Hiess

Energy selection via Bragg reflection from crystals

Point by point investigation of (Q,ω)-space

Diffractometer if analyzer is replaced by multidetector

IN20 Triple-axis spectrometer (ILL, Grenoble)



resolution < 1 meV (depending on conditions)

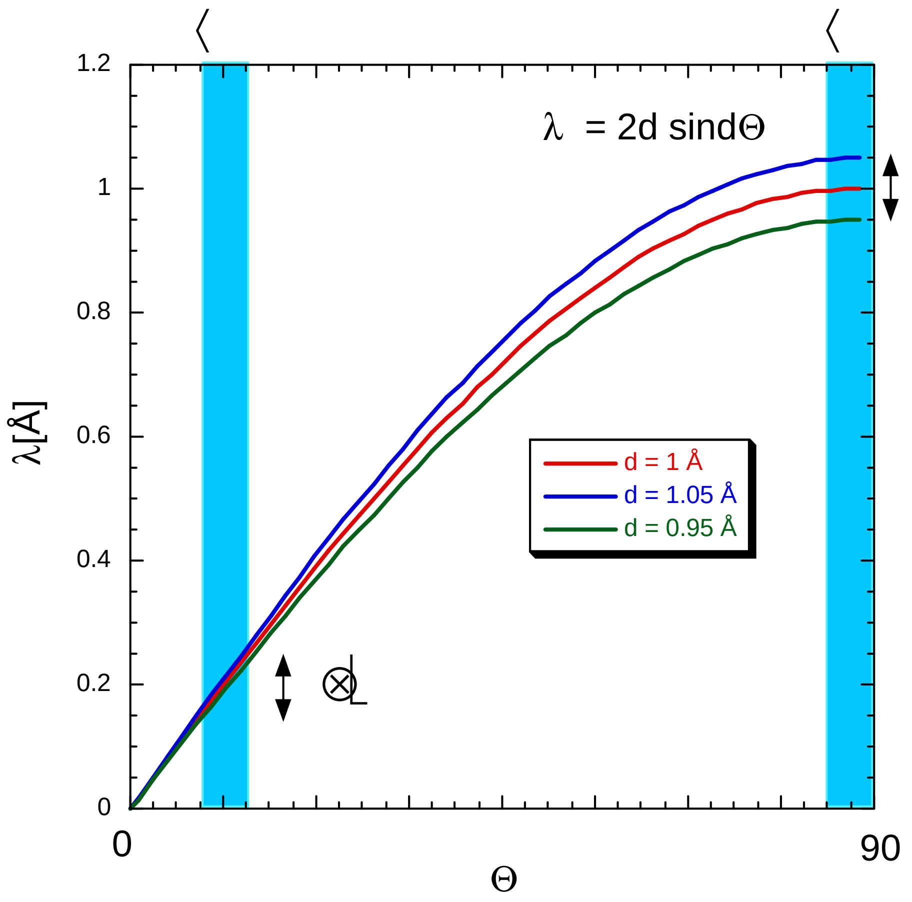
2)

Backscattering spectrometer

Principle:
Energy selection via Bragg reflection from (monochromator) crystal, pushed to the extreme by backscattering

Backscattering Spectrometer IN16 at the ILL

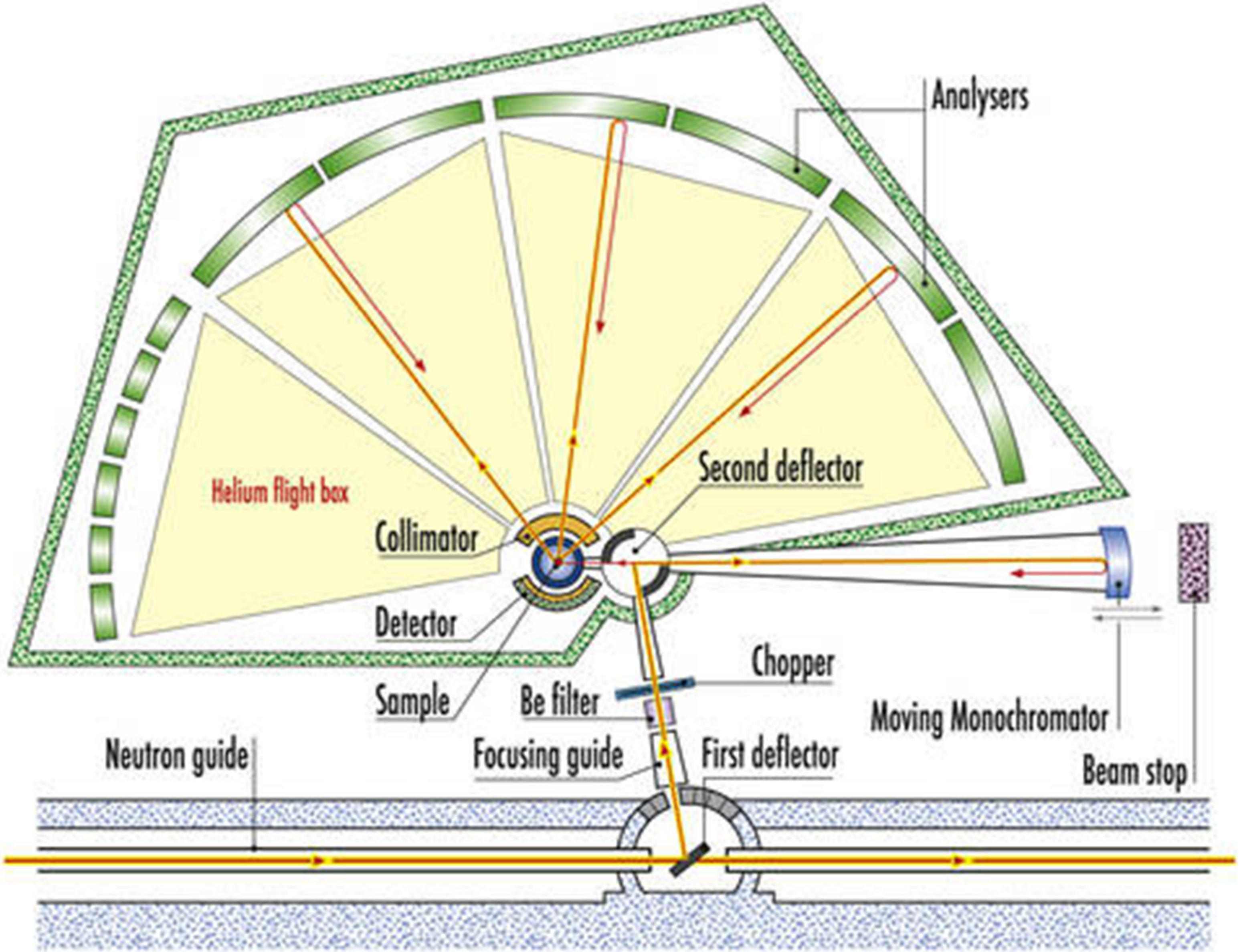
A very special three-axis spectrometer trimmed to
very high (< 1μeV) resolution
or to be used as a fine velocity sensor



Very successfully applied to x-rays

maximize intensity for a given energy resolution

IN16 Backscattering spectrometer (ILL, Grenoble)

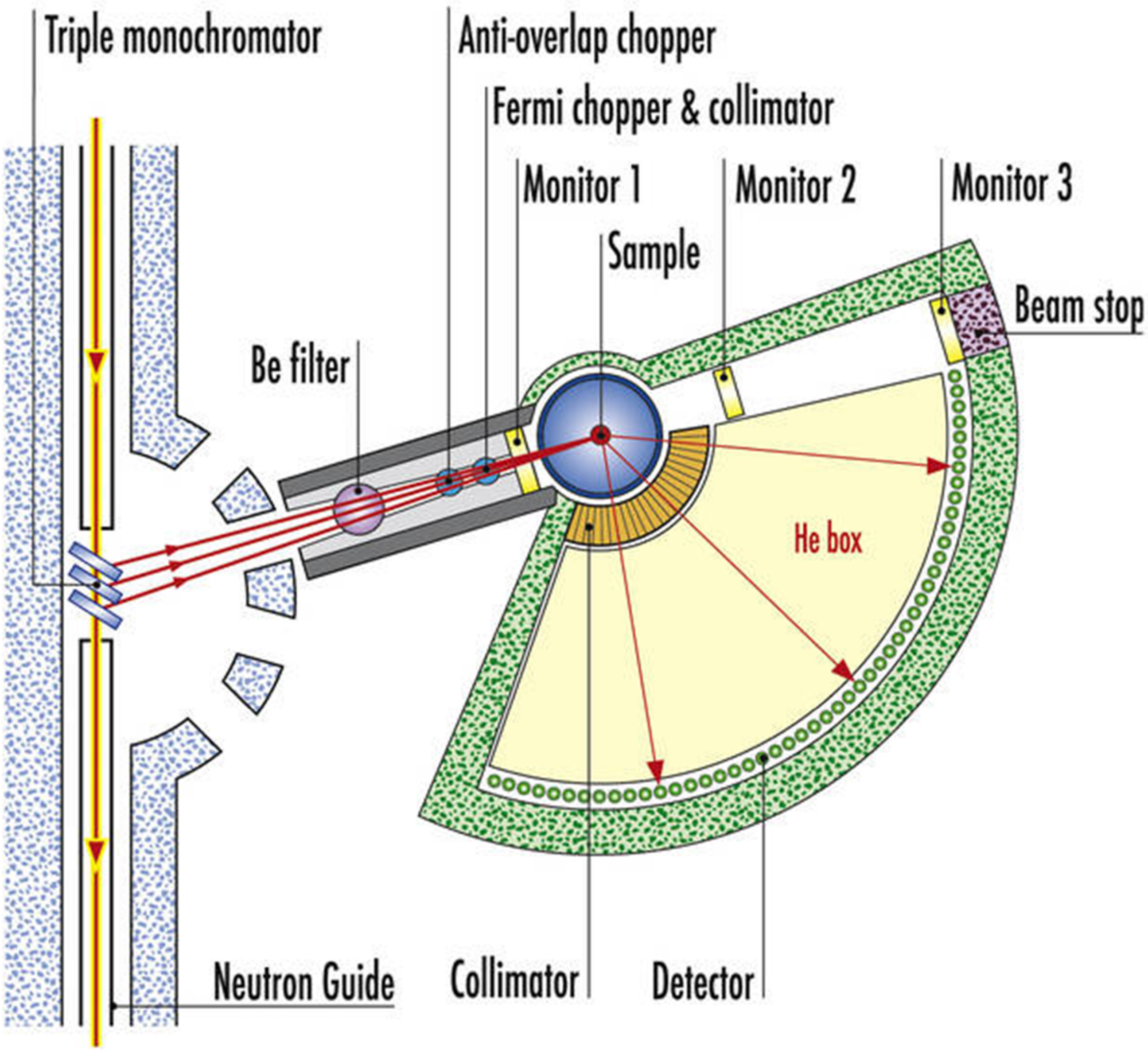


resolution < 1μeV (depending on conditions)

3) Time-of-flight spectrometer

Principle:
Energy selection via neutron velocity (time of flight over a fixed distance)

IN6 time-of-flight spectrometer (ILL, Grenoble)

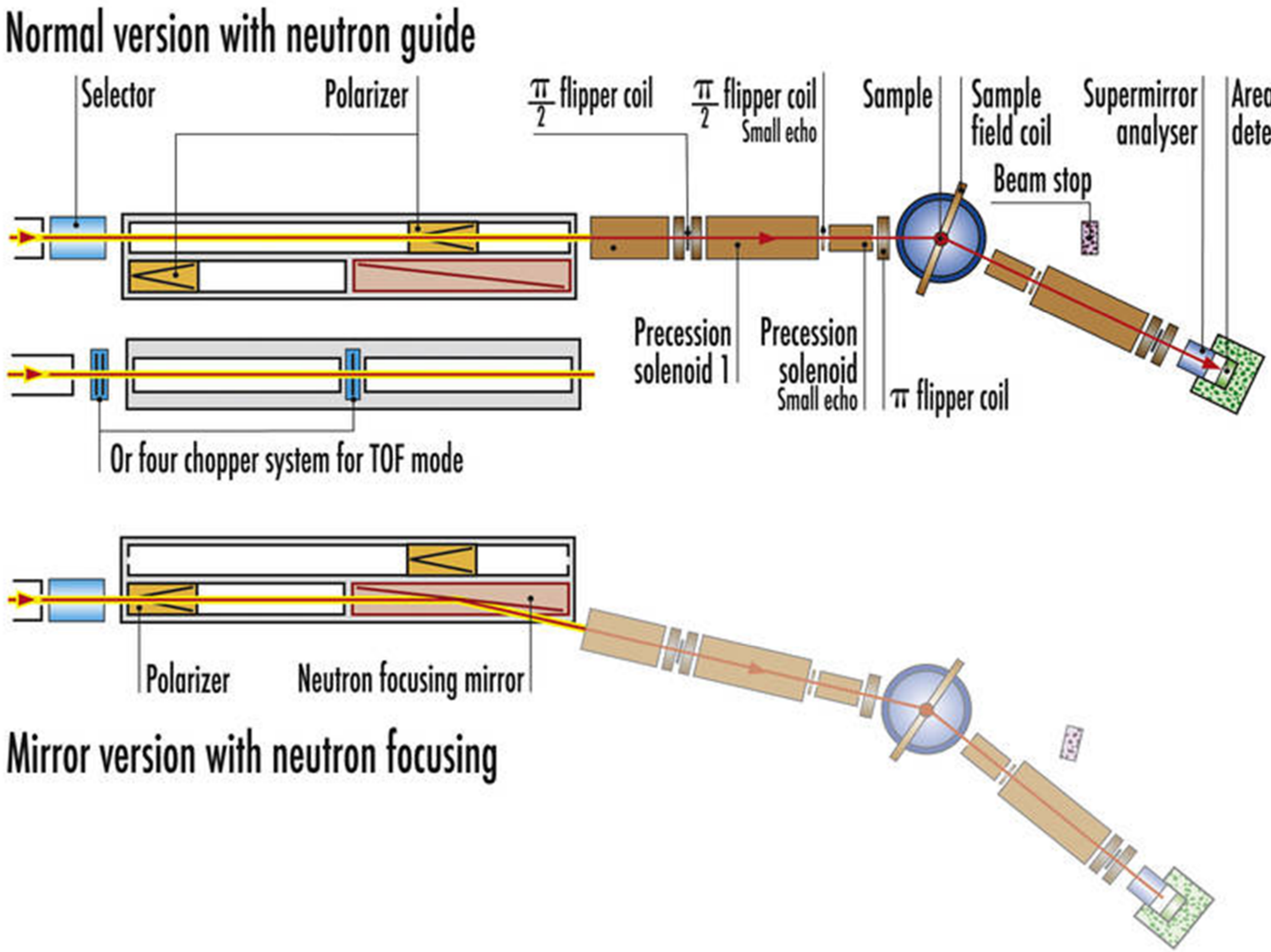


resolution < 100 μeV (depending on conditions)

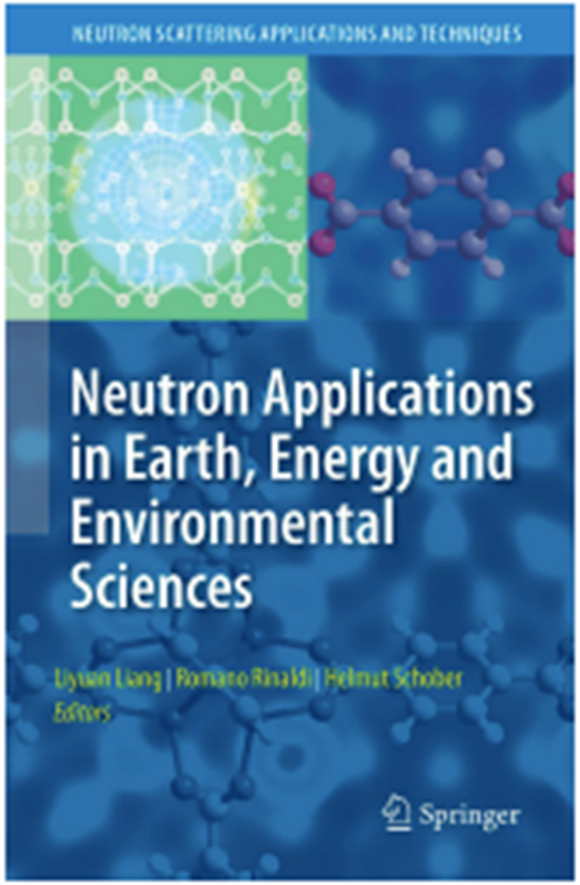
4) Spin-echo spectrometer

Principle:
Energy selection via precession frequency of neutrons in magnetic field

IN15 Spin-echo spectrometer (ILL, Grenoble)



resolution < 1 neV (depending on conditions)



Chapter on Instrumentation

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