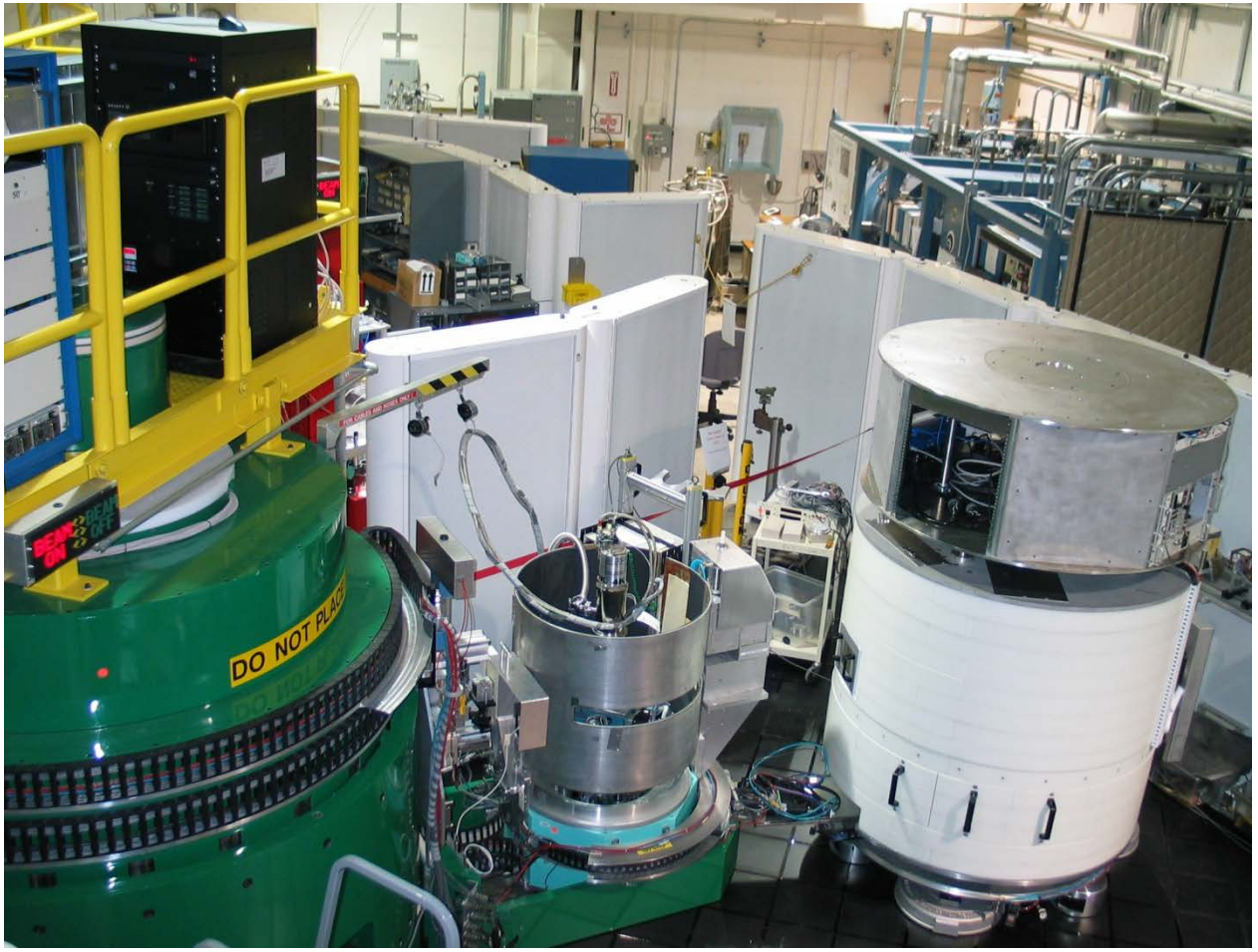
BT-7 Triple-axis Spectrometer



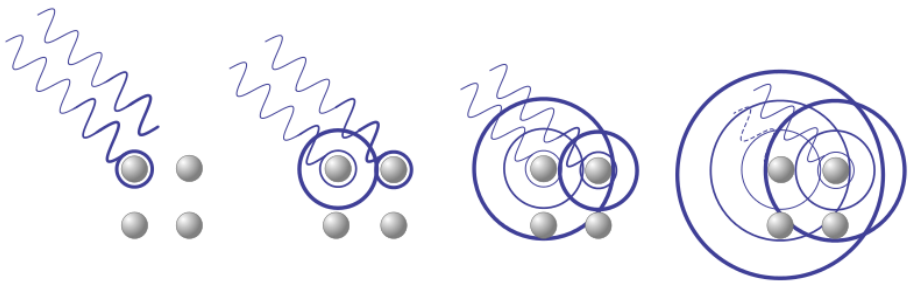
https://www.ncnr.nist.gov/instruments/bt7_new/

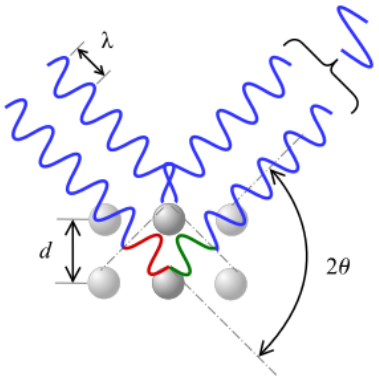
Neutron Basics

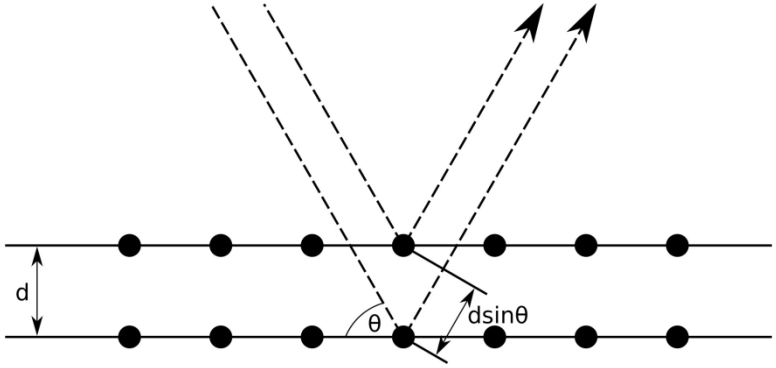
- E = energy
  $E = \hbar^2 k^2 / 2m_n \propto 1/\lambda^2$
- k = wavevector (momentum)
  $k = 2\pi/\lambda$
- λ = wavelength

- BT-7 uses “thermal” neutrons
  Temperature ~300K
  Energy peak ~30meV
  Wavelength ~1.8 Å
- Most common:
  E = 14.7 meV
  $k = 2.66$ Å^{-1}
  $\lambda = 2.35$ Å
- SPINS MACS uses “cold” neutron
- Most common:
  E = 5 meV

Bragg's Law







$n \lambda = 2d \sin\theta$

n=positive integer

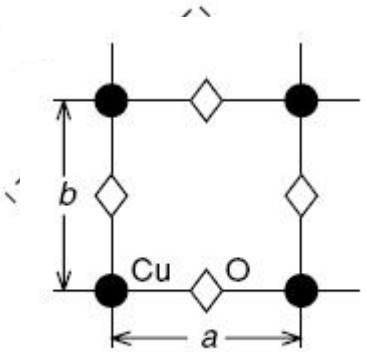
https://en.wikipedia.org/wiki/Bragg%27s_law

Real Space vs. Reciprocal Space

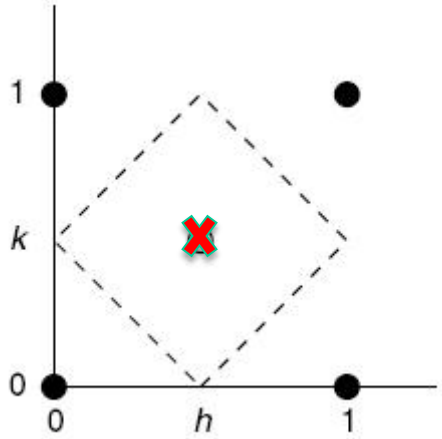
Fourier transformation

Space-time (r,t) → Energy-momentum (Q, hw)

Real space

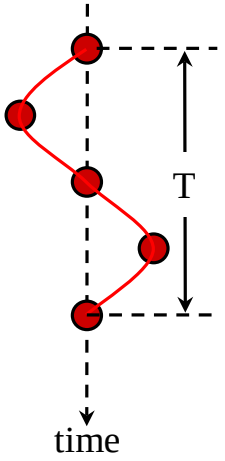


Q-space

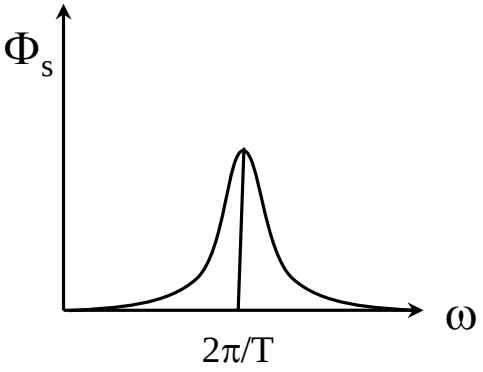


2π/a

Time space



ω-space



Elastic scattering – static structures

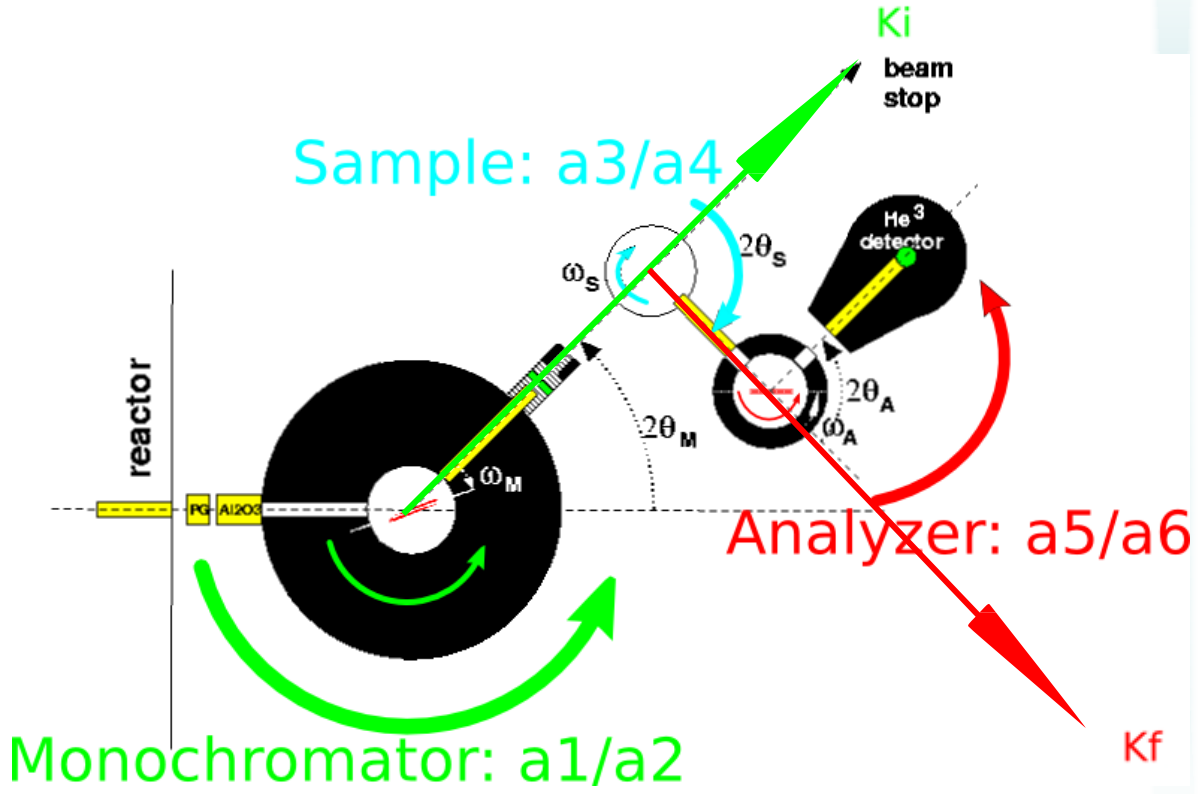
Inelastic scattering – dynamics

Triple-axis Spectrometer

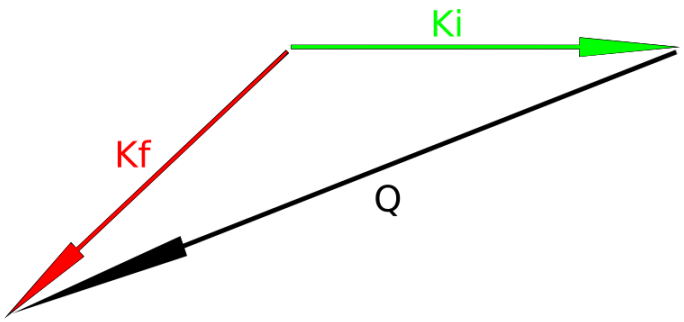
2 out of 3 axes: k_i & k_f

$n\ 2\pi/ k_i = 2d_M \sin(\theta_M)$
$m\ 2\pi/ k_f = 2d_A \sin(\theta_A)$
n, m=1,2,3…

$E_i = \hbar^2 k_i^2 /2m_n$
Controlled by a1/a2
$E_f = \hbar^2 k_f^2 /2m_n$
Controlled by a5/a6



3rd axis : Sample

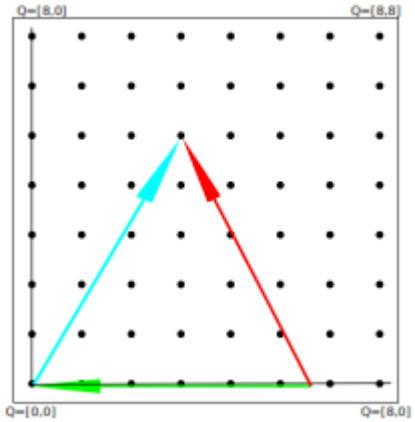


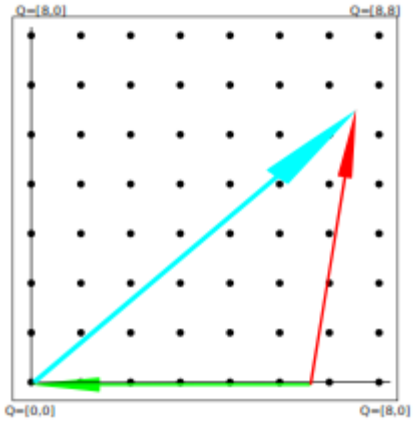
$\mathbf{Q=k_f-k_i}$

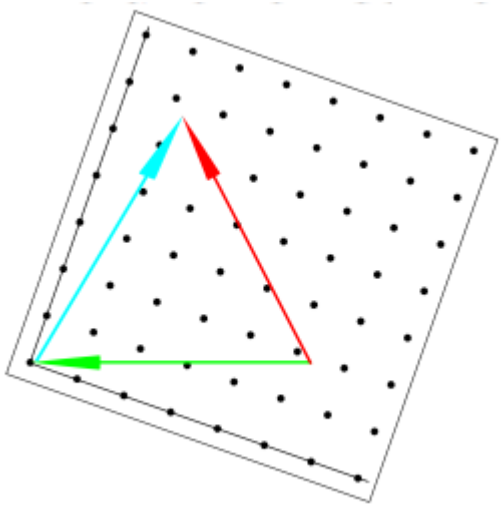
$\hbar\omega=E_i - E_f = 0$ (elastic)

Alignment

a4 : angle between ki/kf a3 : rotation of reciprocal space







Bragg peak!

No peak...

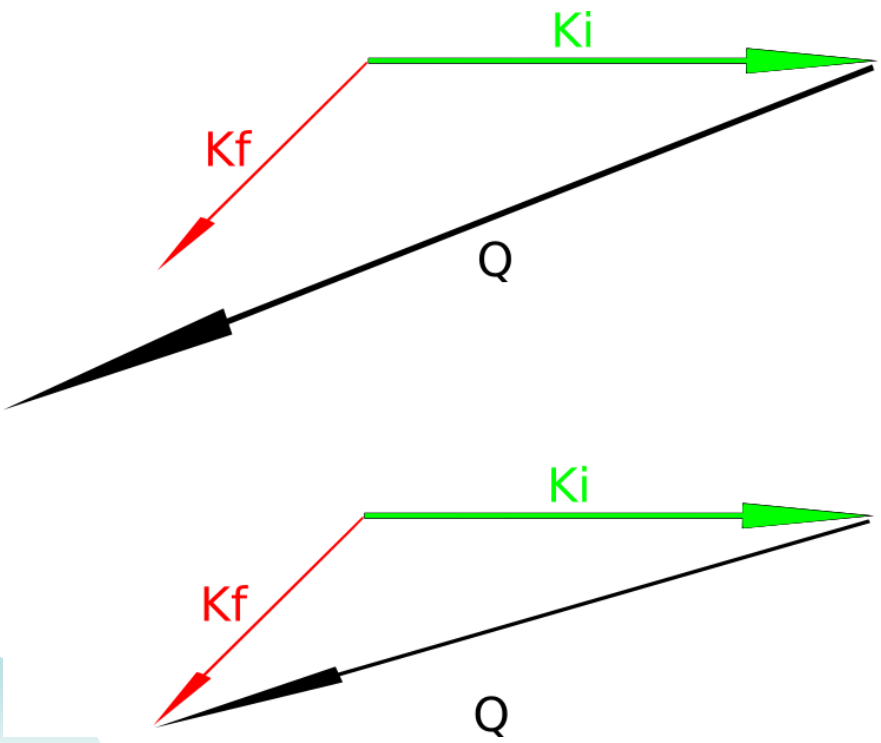
No peak...

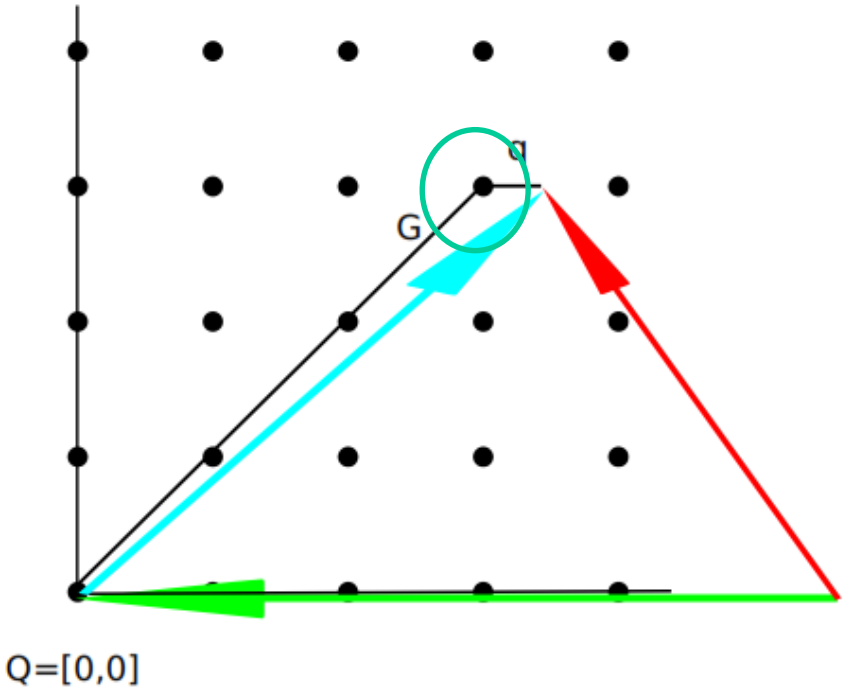
When k_i and k_f aren't equal...

$Q=k_f-k_i$

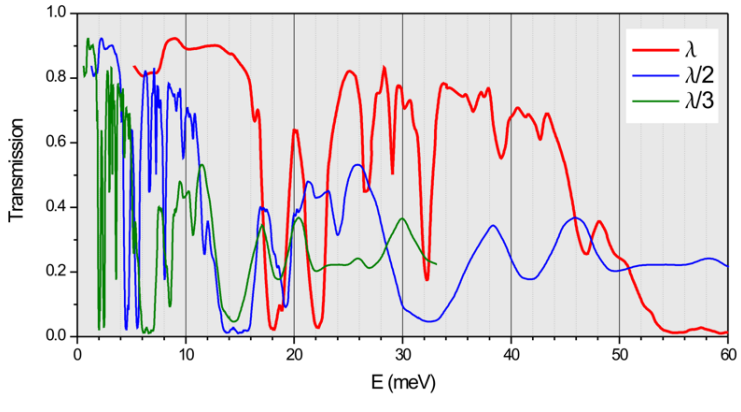
$\hbar\omega=E_i - E_f \neq 0$ (inelastic)

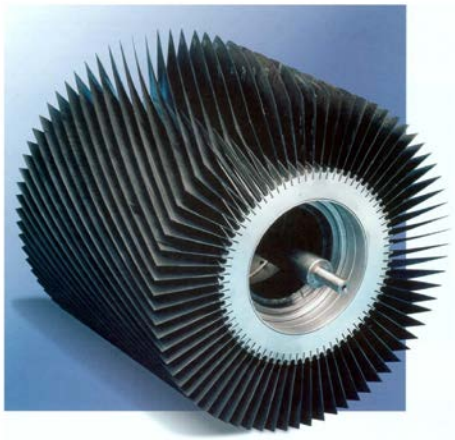
Phonon
Spin wave
and etc

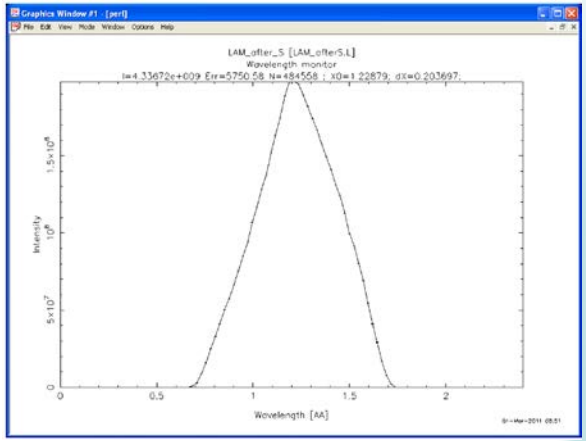




Velocity Selector and Filter







$n\lambda = 2d\sin\theta$

n=positive integer

Pyrolytic Graphite (PG)

E_i= 14.7 meV

$n\lambda = 2d\sin\theta$

n=positive integer

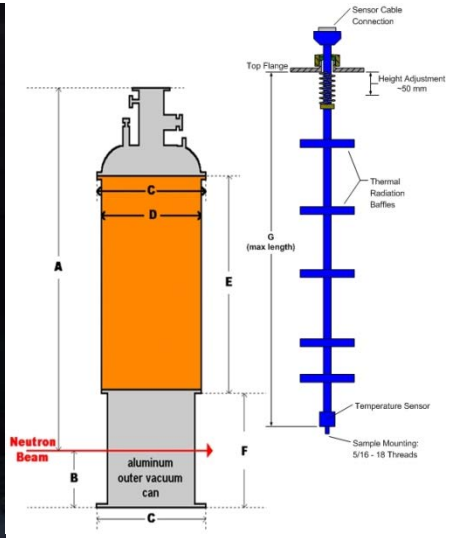
$v_n = L/t \propto f$

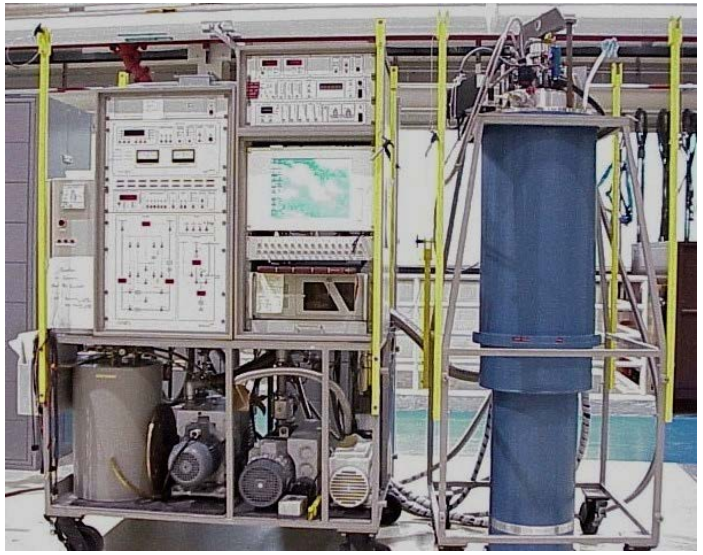
$E_i \propto f^2$

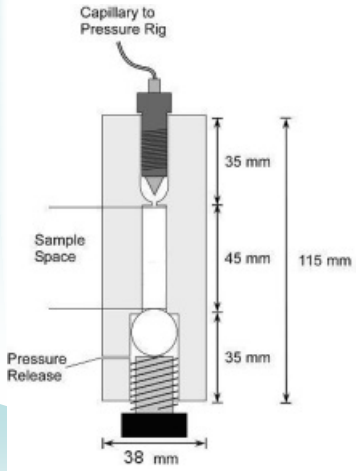
http://www.neutron.ethz.ch/research/resources/graphite-filter-transmission.html

https://www.ncnr.nist.gov/instruments/bt7_new/VelocitySelector.html

Sample Environment







- Low temperature (50mK)
- Magnetic field (15T)
- Pressure (1GPa)
- Furnace (1600C)
- Electric field (5000V)

https://www.ncnr.nist.gov/instruments/bt7_new/
https://en.wikipedia.org/wiki/Bragg%27s_law
http://paulbourke.net/miscellaneous/dft/
https://en.wikipedia.org/wiki/Brillouin_zone
http://www.neutron.ethz.ch/research/resources/graphite-filter-transmission.html
https://www.ncnr.nist.gov/instruments/bt7_new/VelocitySelector.html