Online Card

Backscattering Spectrometer

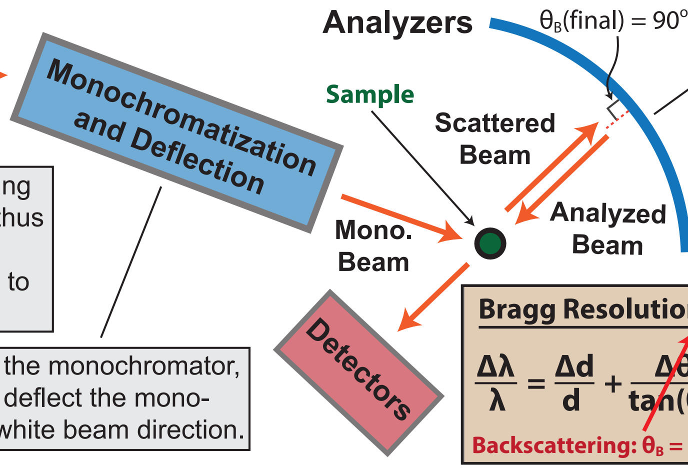
CHRNS — Center for High Resolution Neutron Scattering

NIST Center for Neutron Research

White Beam → **Filtration** → Filtered Beam → Monochromatization and Deflection

The exceptional resolution of backscattering comes at the expense of beam intensity, thus upstream filtration (eg: via crystal filters, choppers, velocity selector, etc.) is critical to achieve good signal to noise.

Either before or after backscattering from the monochromator, a secondary device must be employed to deflect the monochromated beam away from the incident white beam direction.



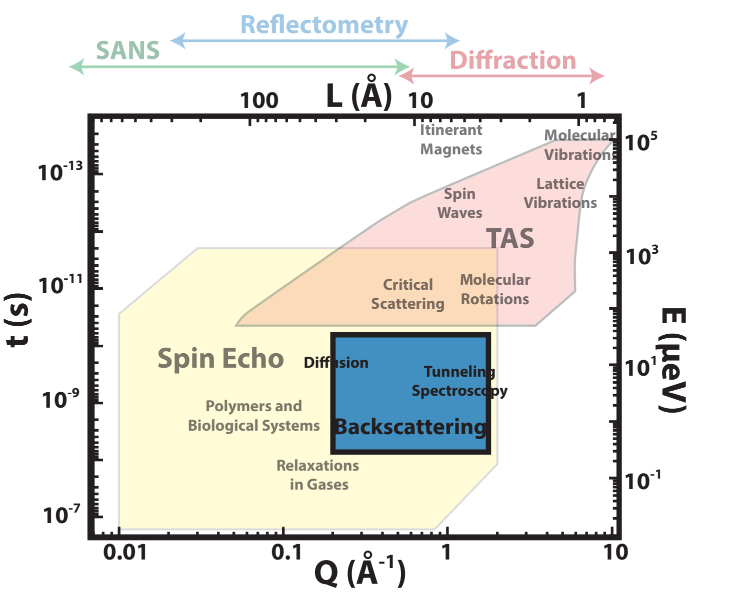
Wide collection analyzer arrays are employed to drastically increase the collection from the inherently weak high-resolution beam.

Bragg Resolution

$$\frac{\Delta\lambda}{\lambda} = \frac{\Delta d}{d} + \cancel{\frac{\Delta\theta}{\tan(\theta_B)}}$$

Backscattering: $\theta_B = 90°$

The backscattering condition reduces the resolution contributions to only lattice variation.



Operating Principles

1) The crystal monochromator and analyzer reflect neutrons with incident energy (E_i) and final energy (E_f).

2) Zero mosaicity and the backscattering geometry provide exceptional energy resolution (~1μeV). However, backscattering on both the monochromator (incident) and analyzer (final) imposes the constraint that their Bragg reflection angles are identical: θ_B(incident) = θ_B(final) = 90°.

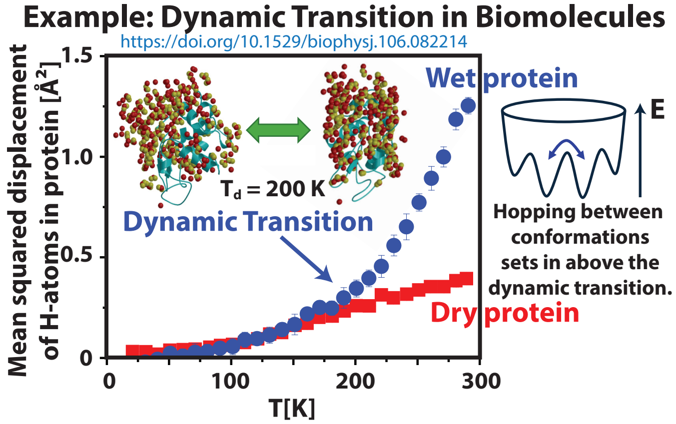
3) **Elastic Geometry:** The monochromator and analyzer use Si(111) crystals which for θ_B = 90° imposes the elastic condition: $E_i = E_f = 2.08$ meV

4) **Inelastic Geometry:** To observe excitations, a Doppler drive monochromator is employed to generate a range of incident energies that still satisfy the backscattered Bragg condition.

5) This dynamic range of incident energies sets the range of energy transfers that can be probed: $E = E_i - E_f$

Example: Dynamic Transition in Biomolecules

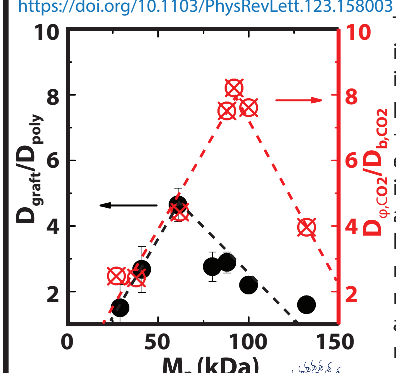
https://doi.org/10.1529/biophysj.106.082214



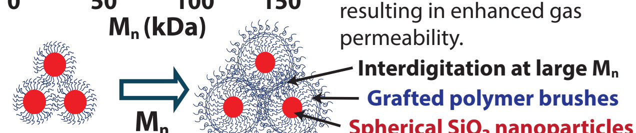
Detection of a dynamic transition in the hydrated protein, Lysozyme. Dynamic transitions are crucial biological functions, enabling processes like signaling, molecular recognition and catalysis.

Example: Control of Gas Permeability via Polymer Dynamics

https://doi.org/10.1103/PhysRevLett.123.158003



The diffusivity (D) of light gases in grafted nanoparticles (GNP) is improved over neat polymers, peaking at specific graft molecular weights (M_n). This enhancement is linked to increased local chain dynamics and the length of segment hops, which vary with graft molecular weight. These dynamical aspects lead to alterations in polymer densities, resulting in enhanced gas permeability.



Instrument Webpage

High Flux Backscattering Spectrometer (HFBS)

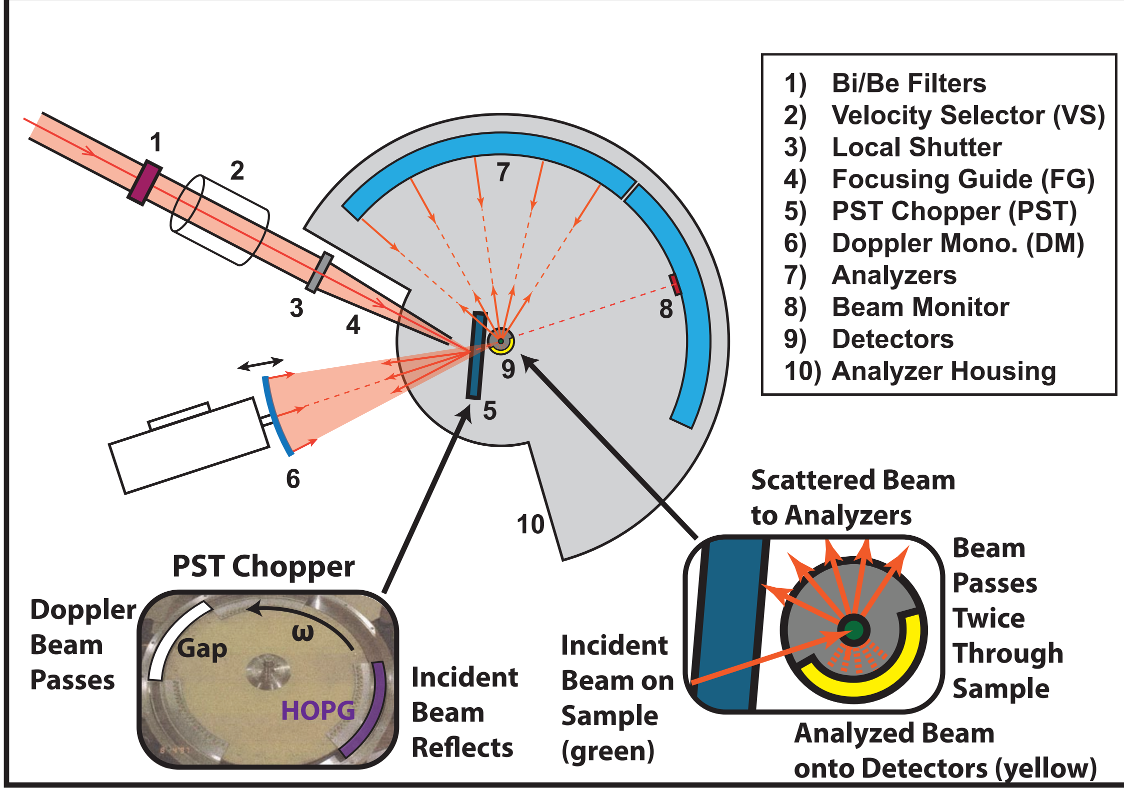
Instrument Paper: https://doi.org/10.1063/1.1568557

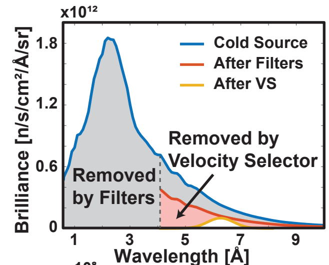
Instrument Webpage: https://www.nist.gov/ncnr/high-flux-backscattering-spectrometer

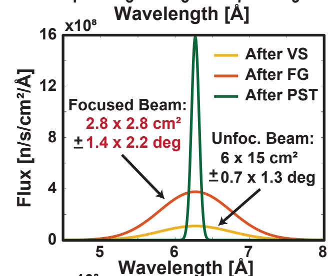
CHRNS CENTER FOR HIGH RESOLUTION NEUTRON SCATTERING

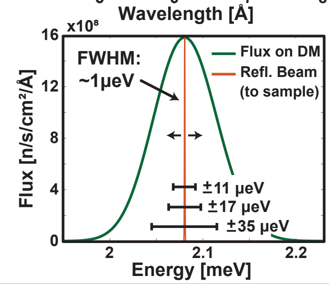
NIST CENTER FOR NEUTRON RESEARCH

The High Flux Backscattering Spectrometer (HFBS) is an inverted geometry spectrometer capable of resolving motions with characteristic times of the order of a few nanoseconds. With a dynamic range up to 35 μeV and an energy resolution of ~0.8 μeV, HFBS offers the highest count rate with sub-μeV resolution in the US. The instrument characteristics make HFBS an ideal choice for high resolution, quasi-elastic scattering studies of low-energy dynamics in polymers, biomolecules, adsorbed species, and molecular reorientations.









Instrument Characteristics

Beam Size: 3 x 3 cm²

Length Scales: 4 Å - 25 Å (Q: 0.25 $Å^{-1}$ - 1.75 $Å^{-1}$)

Time Scales: 50 ps - 2 ns

Sample Flux: 5.0 x 10^5 n/cm²/s

Resolutions:

Dynamic Range	FWHM
11 μeV	0.80 μeV
17 μeV	0.85 μeV
35 μeV	1.20 μeV

Cryostats

System	Range
Top Loading CCR	2.5 K - 700 K
High-Temp CCR	14 K - 800 K
ILL Orange Cryostat	1.5 K - 300 K
ICE Dil Fridge	50 mK - 300 K
Furnace	473 K - 1673 K

Pressure

System	Restrictions
Powder Samples: 5 kbar	1.5 K - 300 K
Liquid Samples: 1 kbar	275 K - 320 K

Sample Holders

Liquids: Annular sample holder

Powders: Flat plate sample holder

Electrochemical cell for battery applications

Filtration

- **Bi/Be Filters: 30 cm of Be, 10 cm of Bi**

Filtered Particle	Transmission
[core gammas, fast neutrons, cold neutrons]	[0.2%, 0.06%, 53%]

- **Velocity Selector:** $\Delta\lambda/\lambda$ = 18%, Transmission 83%

Flux Gain Components

- **Focusing Guide:** x8 gain
  - Beam Compression: 2.8 x 2.8 cm²
  - Divergence Relaxation: 2.1°
- **PST Chopper:** x4.2 gain
  - Duty Cycle: 50%
  - HOPG Crystals: 7.5° mosaic

Monochromator

- **52 x 28 cm² area:** Comprised of ~15 hexagonal wafers
- **Spherically Curved:** r = 2.12 m
- **Si(111) (strained perfect crystal):**
  d_{111} = 3.135 Å (λ = 6.27 Å, E_i = 2.08 meV), $\Delta\lambda/\lambda = 1.86\text{x}10^{-5}$
- **Doppler Drive (3 dynamic ranges):**
  ±11 μeV, ±17 μeV, ±35 μeV,

Analyzer System

- **Analyzer Area:**
  8 spherical sections (each 36.4 x 201 cm), 39.3° < 2θ < 124.3°
  4 Debye-Scherrer rings, 7.8° < |2θ| < 39°
- **Si(111) (strained perfect crystal)**
- **Spherically Curved:** r = 2.05 m
- **Coverage:** 23% of 4π steradians, 7.8° < 2θ < 124.3°

Detector Assembly

- **13 He3 pencil detectors:** 7.75° angular acceptance each
- **4 separate He3 detectors:** Each captures a Debye-Scherrer analyzer ring.