NaY Zeolite Templated Carbons

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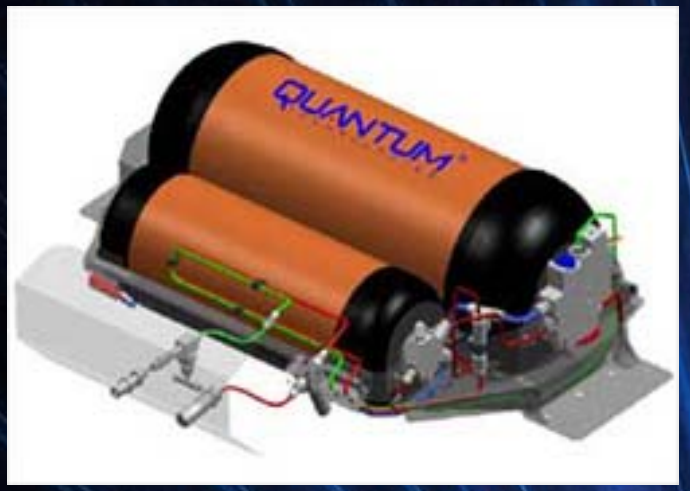
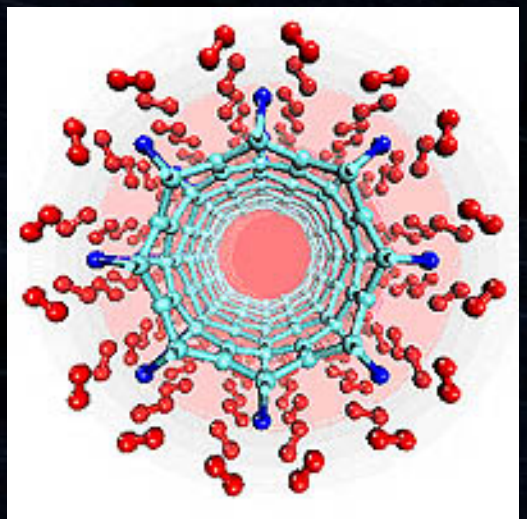
Hydrogen Storage Background

- Makes use of renewable energy sources
- Reduced dependency on foreign oil
- Reduced environmental impact
- Zero greenhouse gas emissions
- Potentially reduced cost
- Higher efficiency

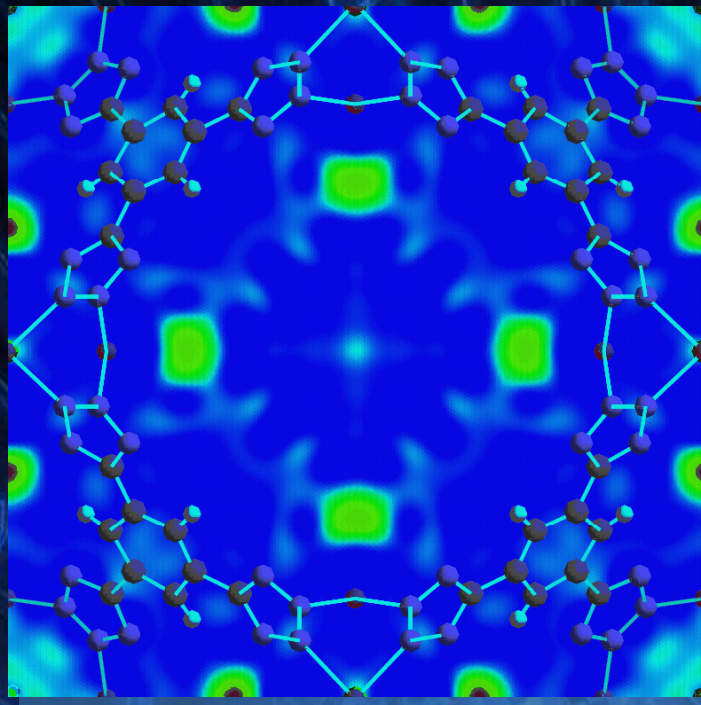
Hydrogen Storage

- Compressed
- Liquid
- Chemisorption
- Metal Hydrides
- Physisorption





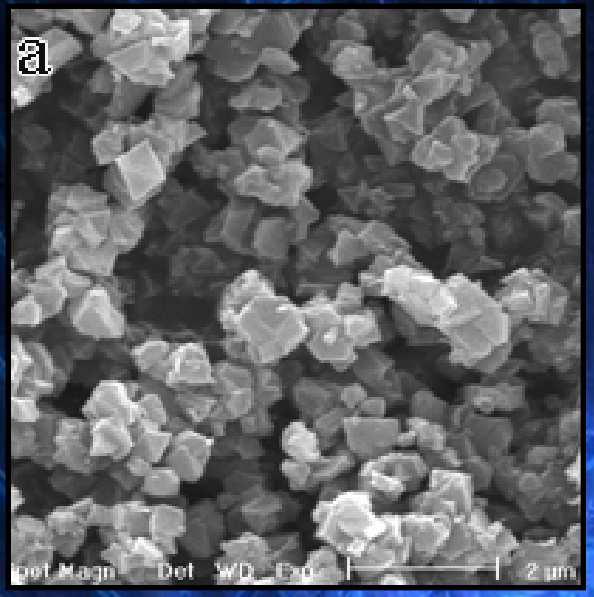
Physisorption

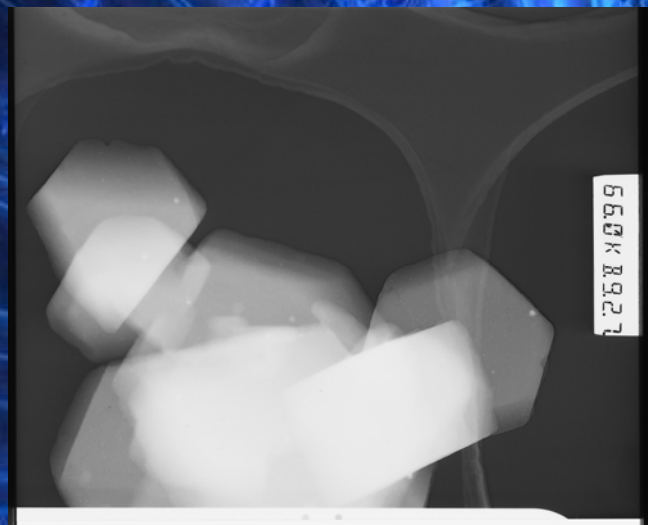


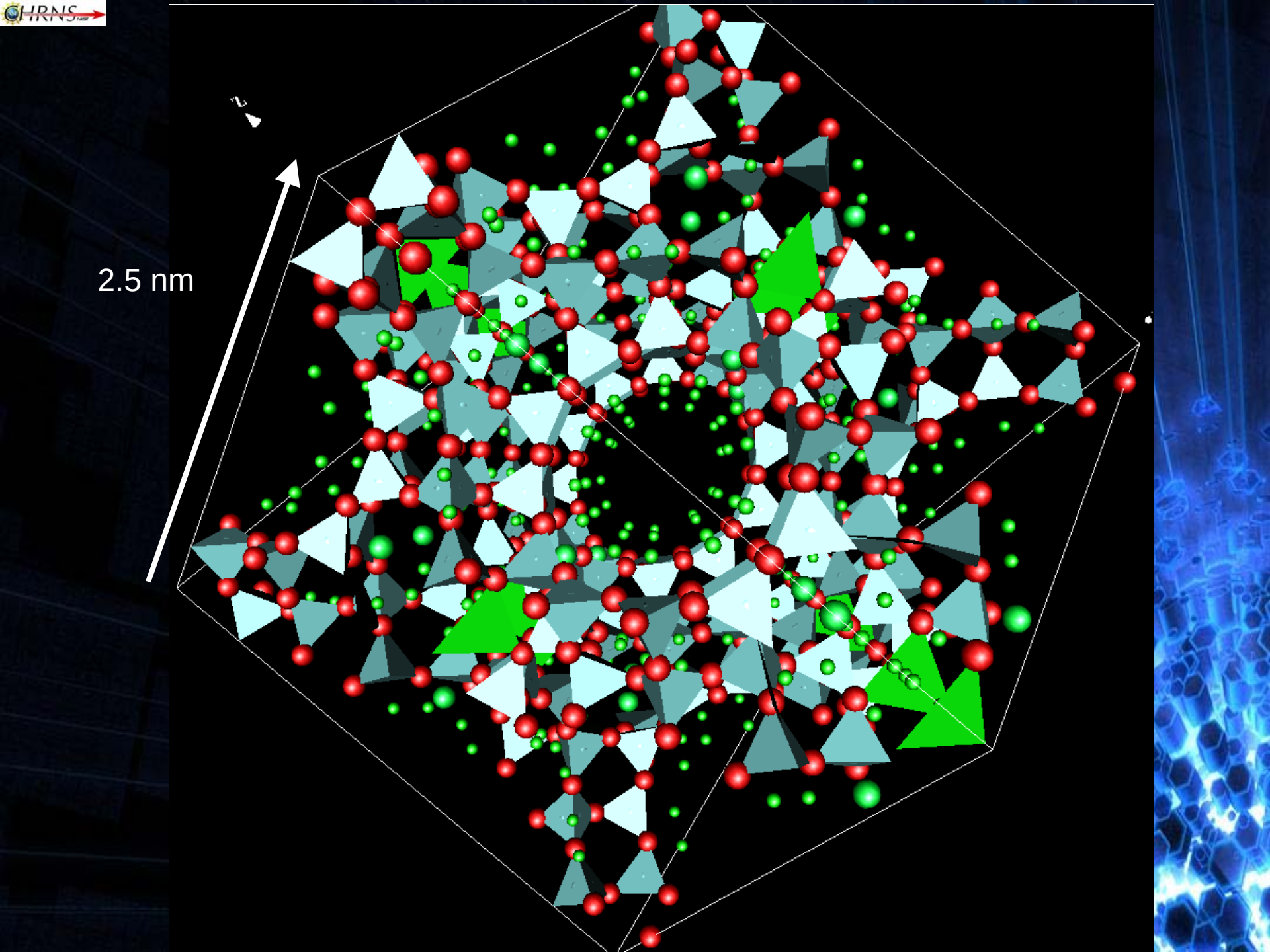
- Advantages
  - Fast kinetics
  - Low pressures
  - Relatively low cost
  - Simple storage mechanisms
  - Fully reversible
- Disadvantages
  - Currently poor gravimetric and volumetric capacities
  - Currently low binding energies requiring very low operating temperatures

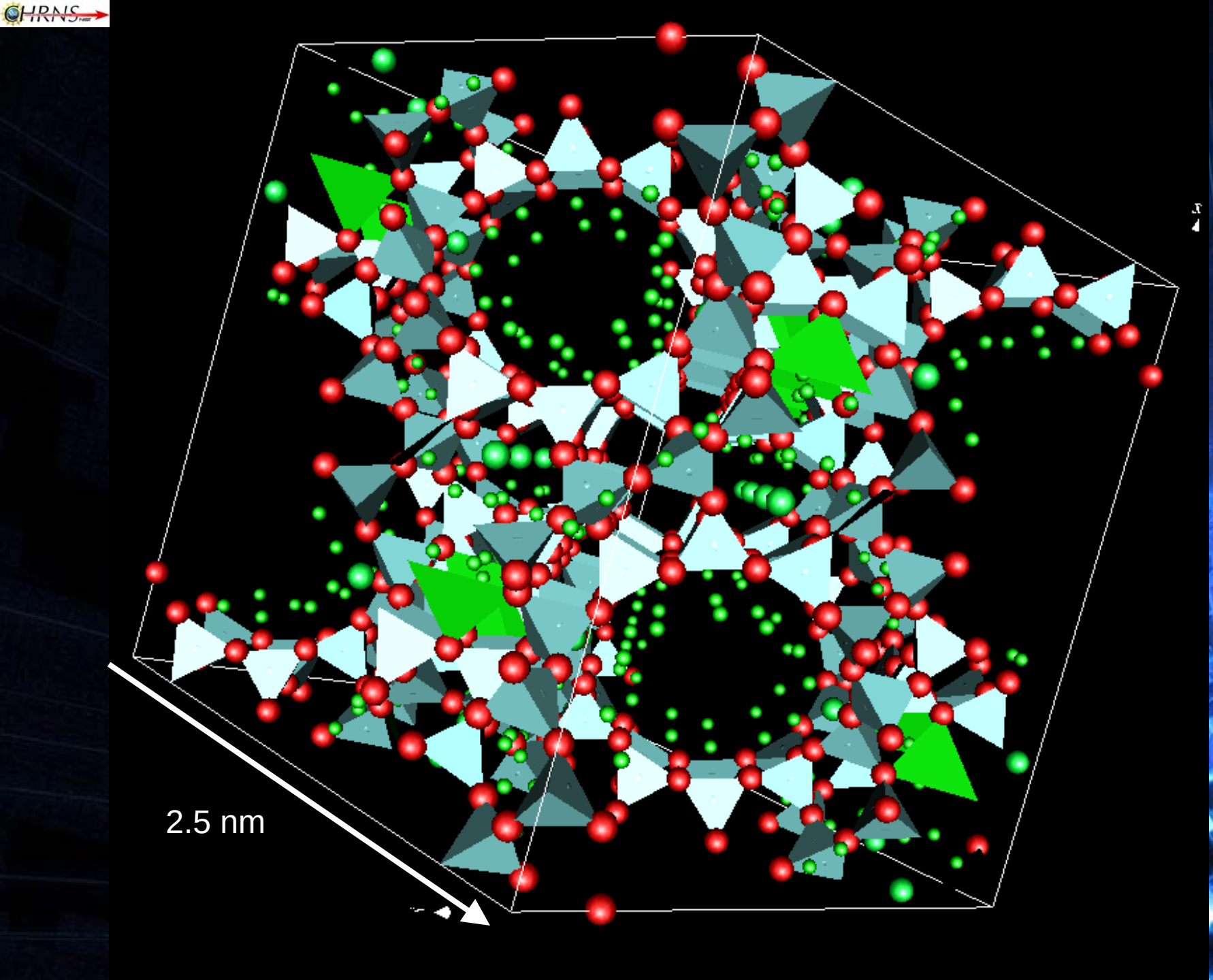
NaY Zeolite Templated Carbon

- Prepared at Monash university in Australia
  - NaY zeolite degassed and impregnated with furfuryl alcohol
  - Polymerized in a vertical quartz reactor
  - Carbonized and then chemical vapor deposition with propylene gas
  - Inorganic Supports removed by use of Hydrofluoric acid after heat treatment
  - Extensive filtering and washing with purified water
  - Finally dried in a vacuum at 30c for 24 hours



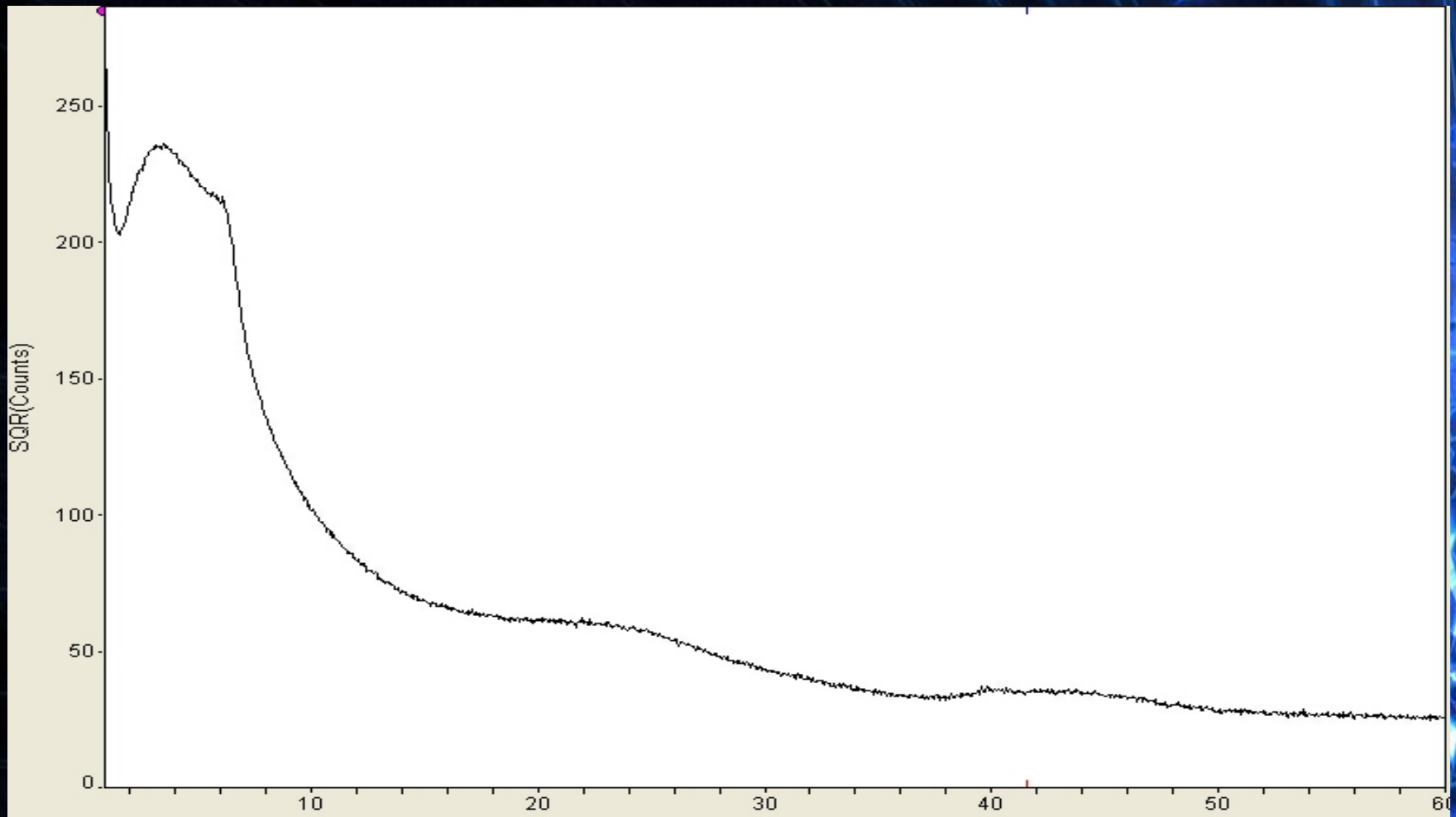



2.5 nm


2.5 nm

X-Ray Diffraction

- Probes for any regular structure within the sample by using X-rays to observe the phenomena of diffraction (make sure NaY is gone)
- This is an amorphous material and thus we expect no diffraction patterns (Bragg peaks)
- Only detects very small range structure, sub angstrom to 10s of angstroms

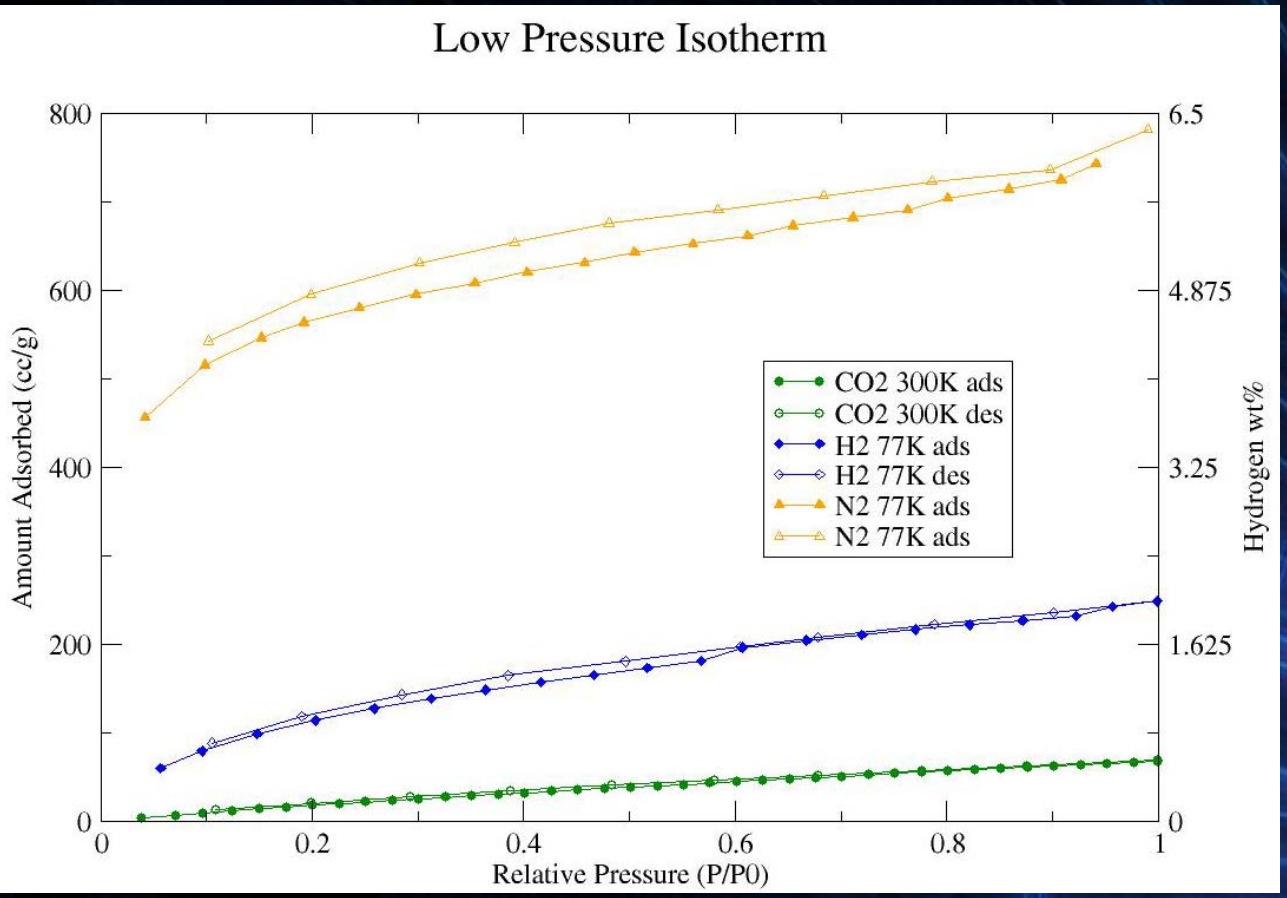


Low Pressure Isotherms

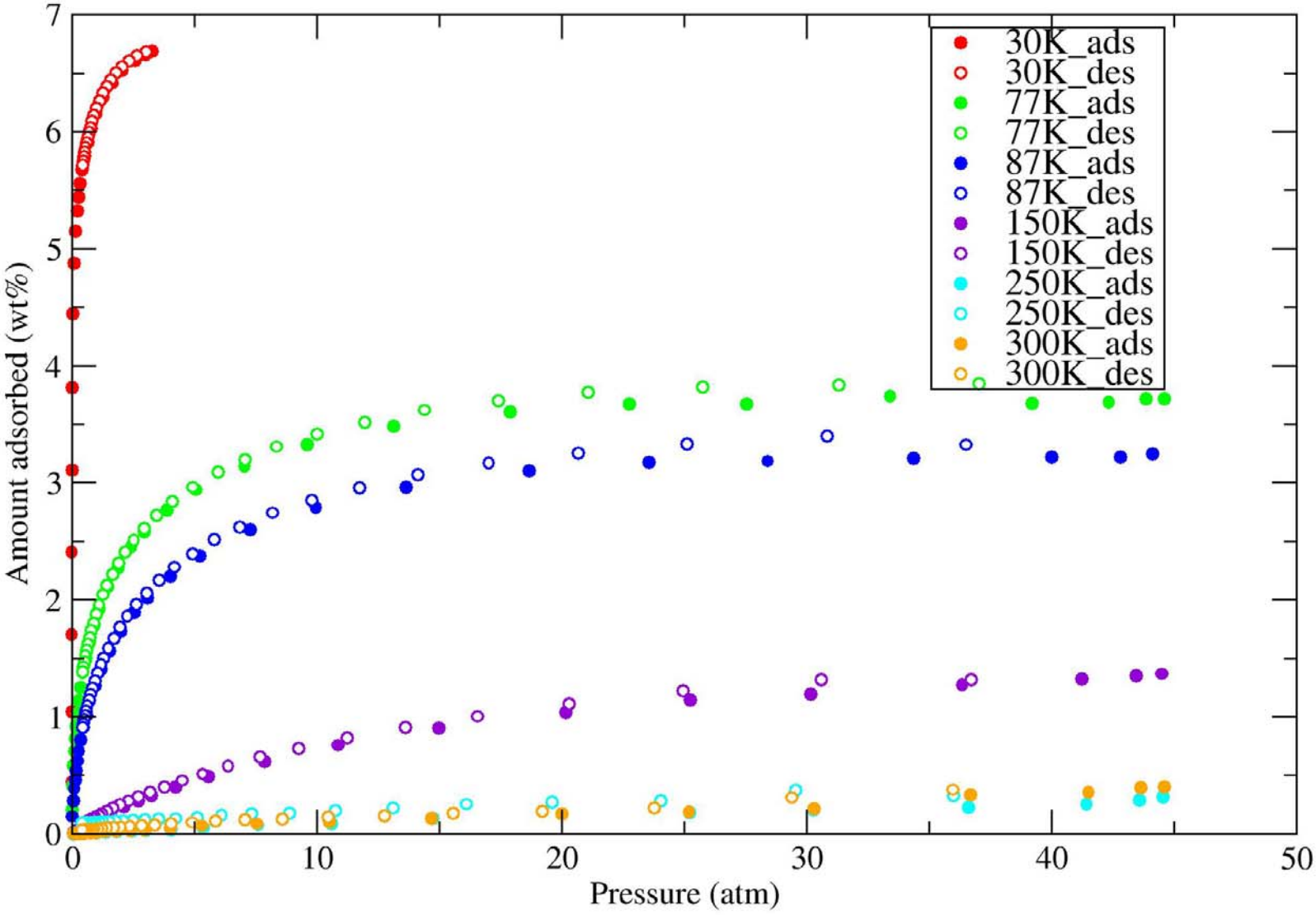
- Sample outgassed overnight at 200c
- Performed with CO_2, N_2, and H_2 at 294K, 77K, and 77K respectively
- 52.9mg tested on Quantachrome isotherm instrument

N_2 BET SA: 1304 m^2/g

H_2 Langmuir SA: 1060 m^2/g

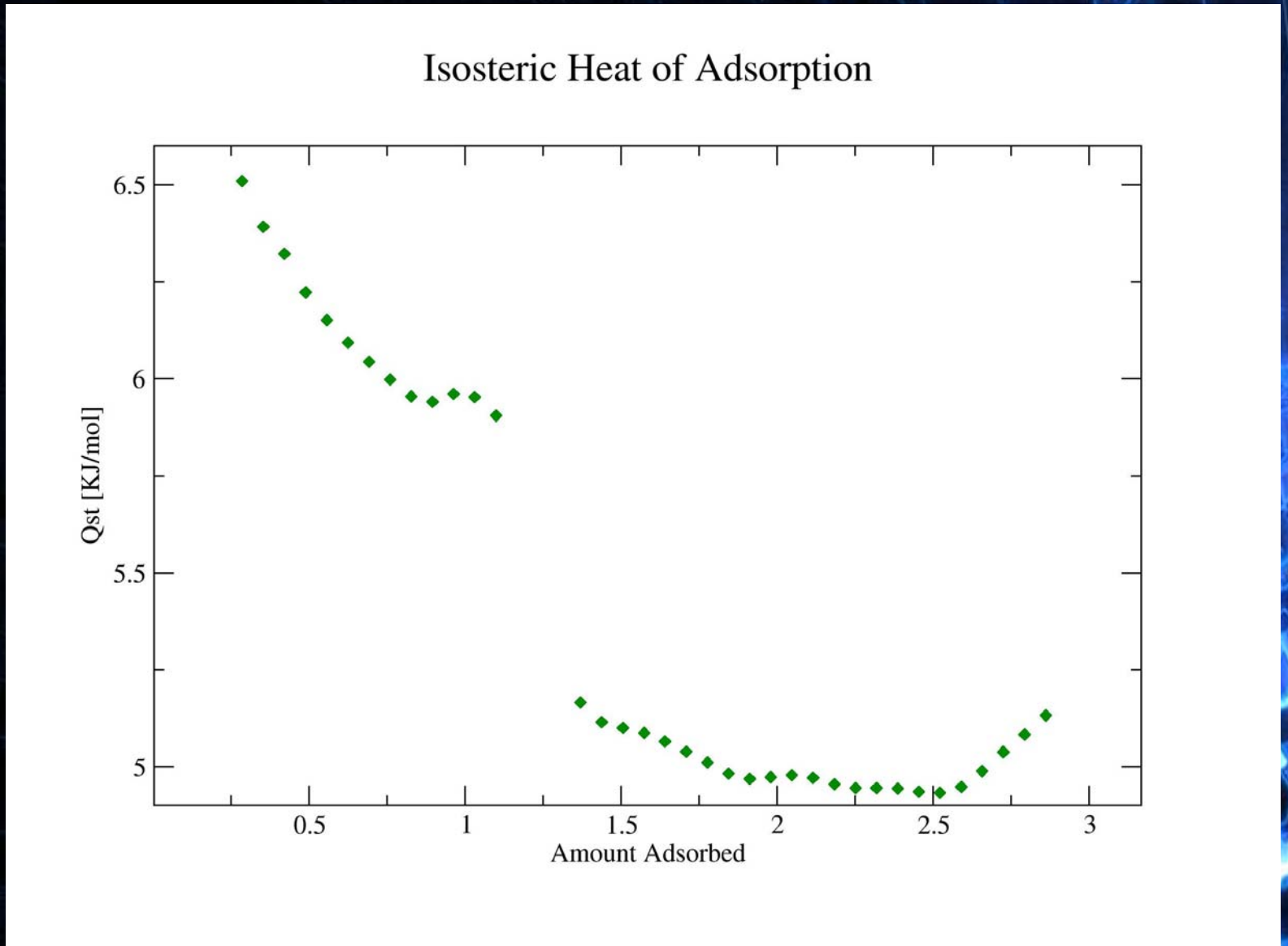


Excess Adsorption Isotherms



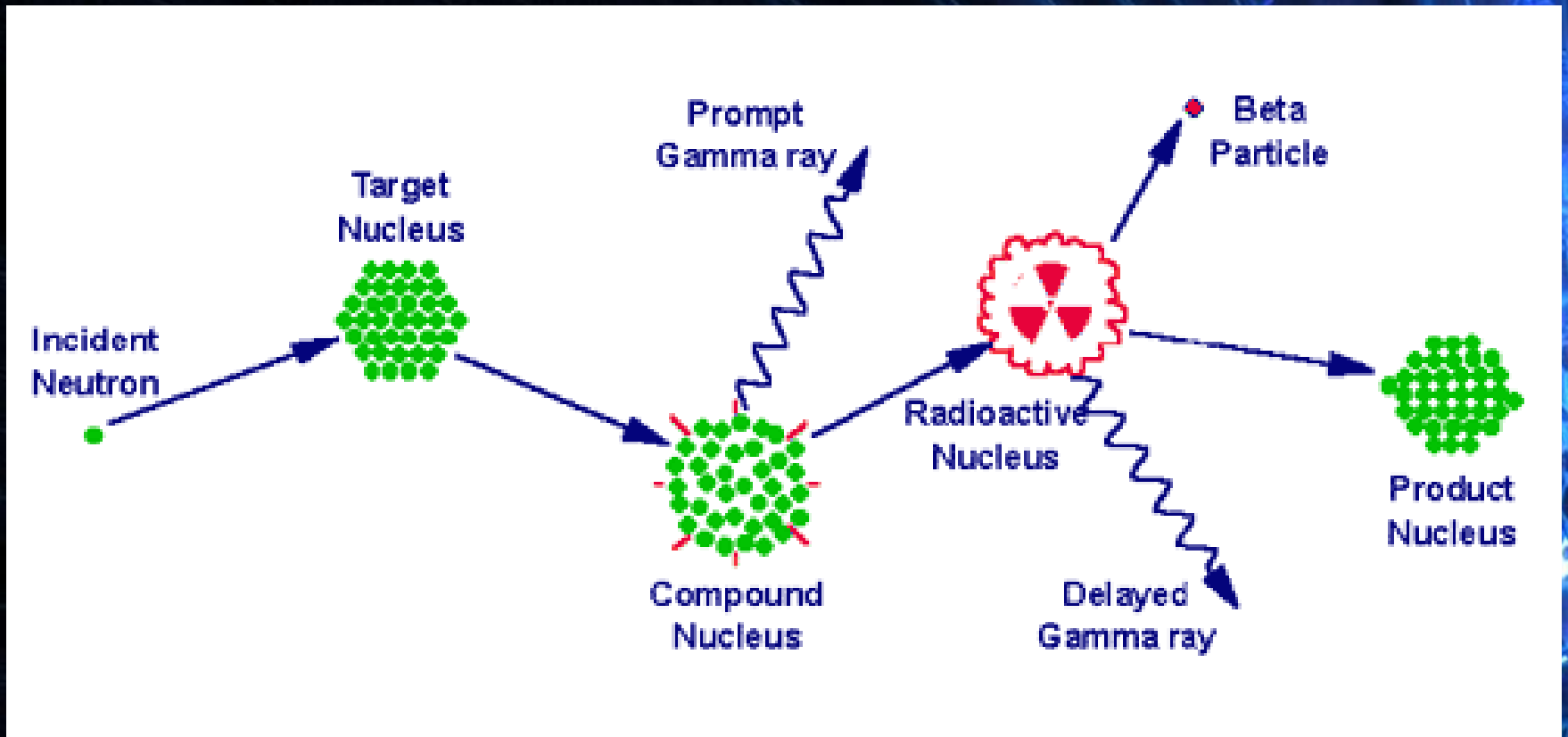
High Pressure Isotherms

- Affinity of hydrogen to loading sites
- Decreases with increased loading
- Decreases with increased temperature

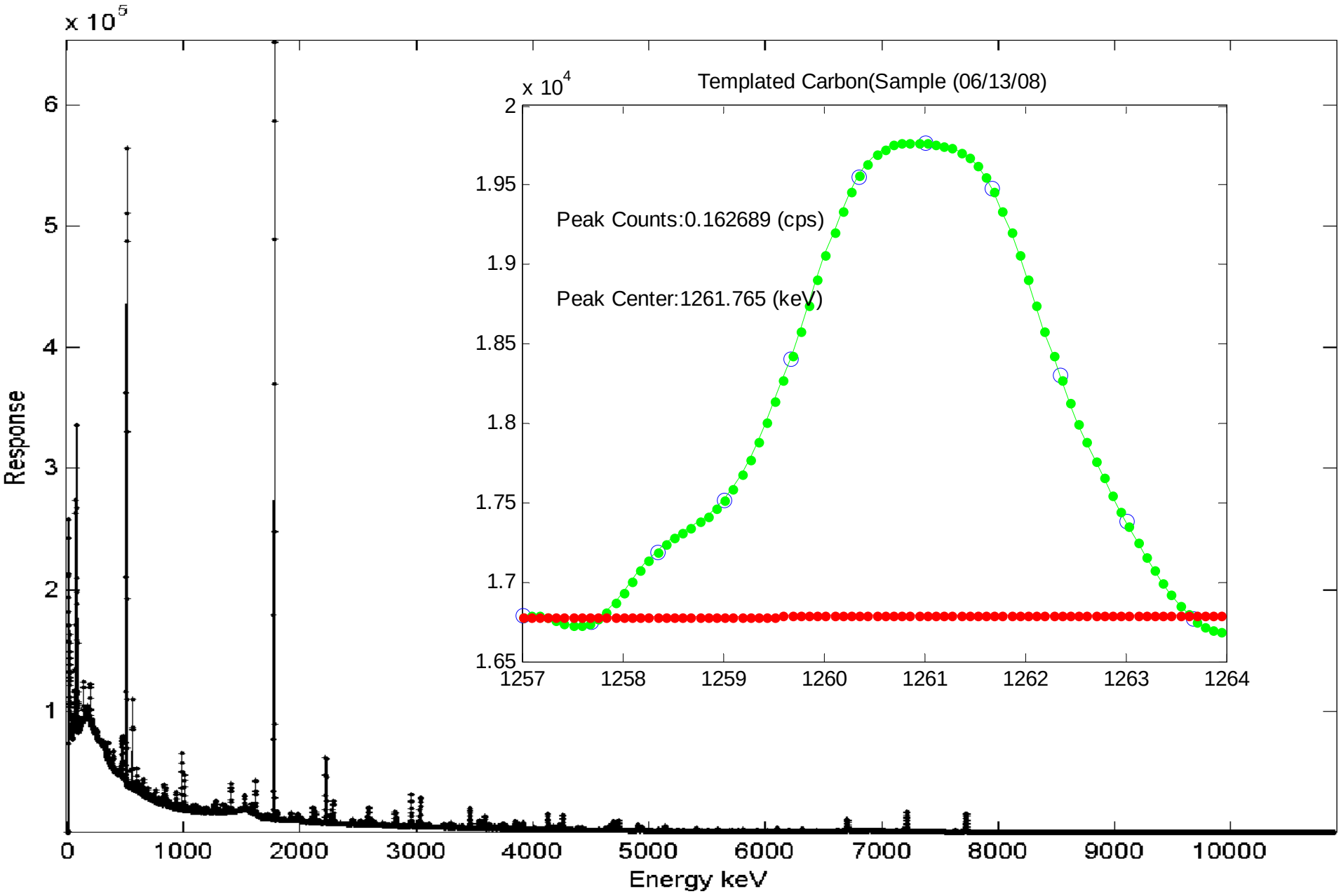


NG7 Prompt Gamma Activation Analysis

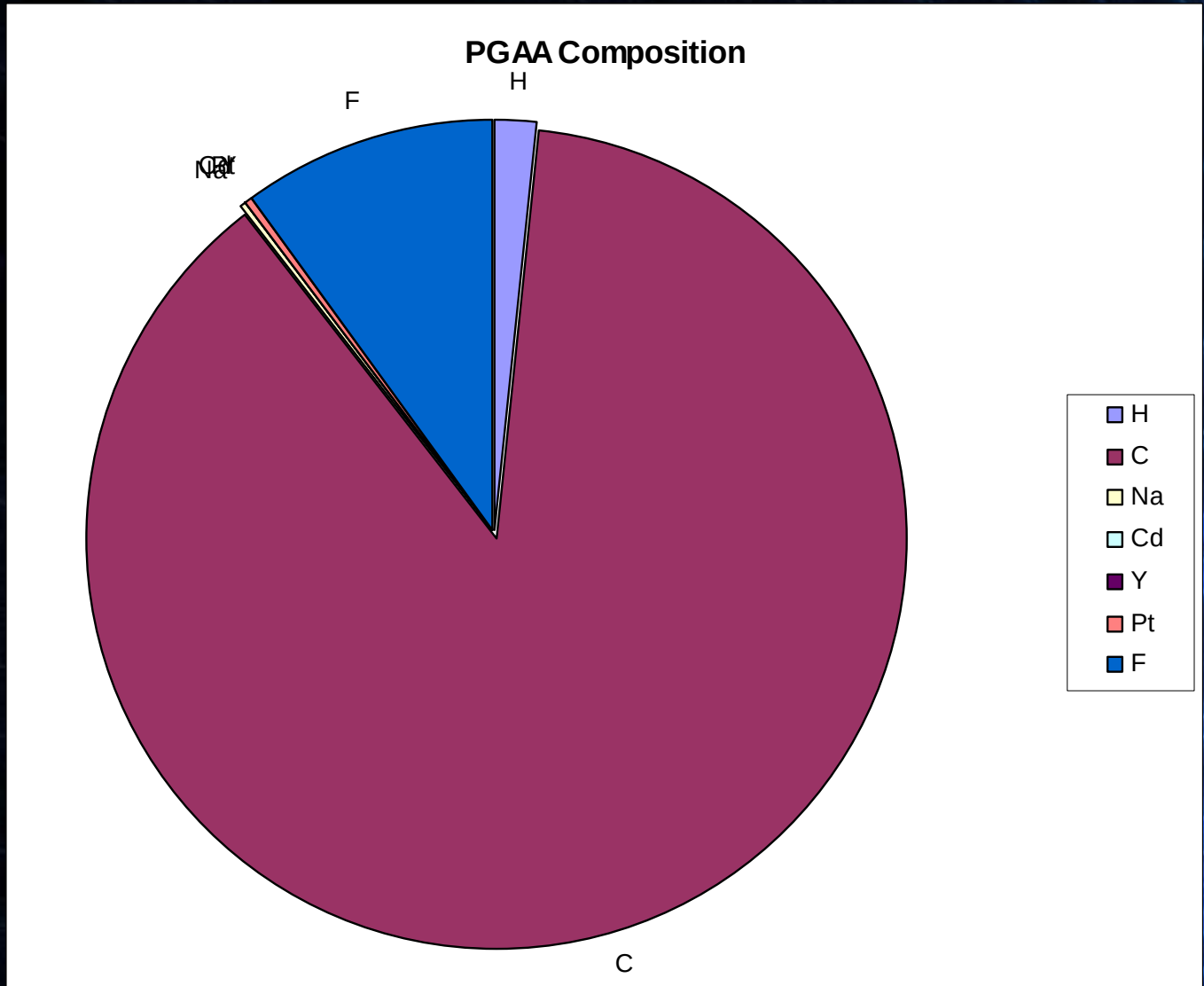
- Each type of atom releases gamma rays of a certain energy level(s) when bombarded with neutrons
- We detect these gamma rays and based on the sensitivity and energy level can determine the approximate proportions of each element.



PGAA Data

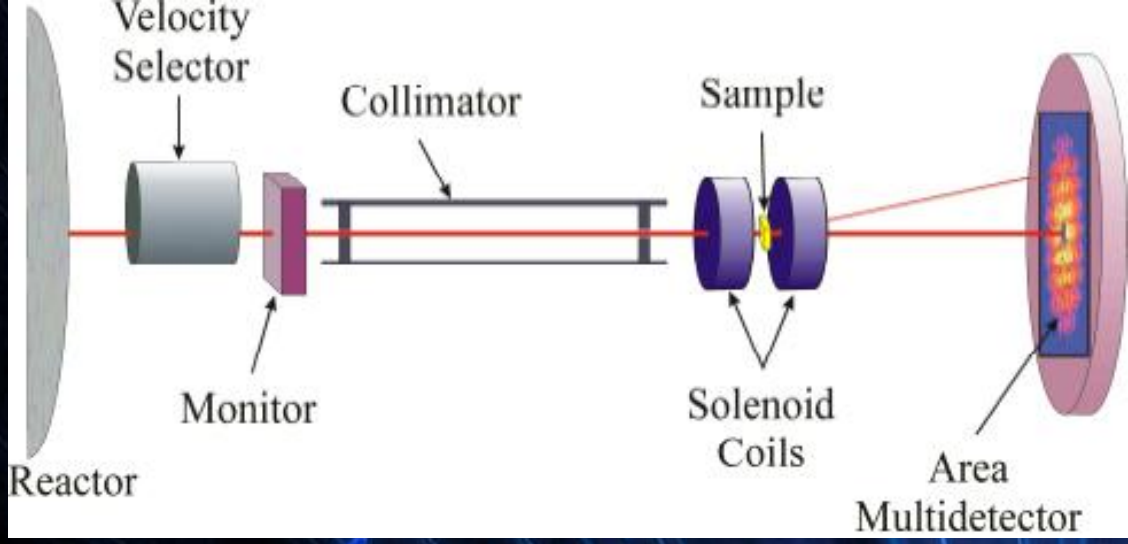

x 10^5
Response
Energy keV
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
1
2
3
4
5
6
x 10^4
Templated Carbon(Sample (06/13/08)
Peak Counts:0.162689 (cps)
Peak Center:1261.765 (keV)
1.65
1.7
1.75
1.8
1.85
1.9
1.95
2
1257
1258
1259
1260
1261
1262
1263
1264

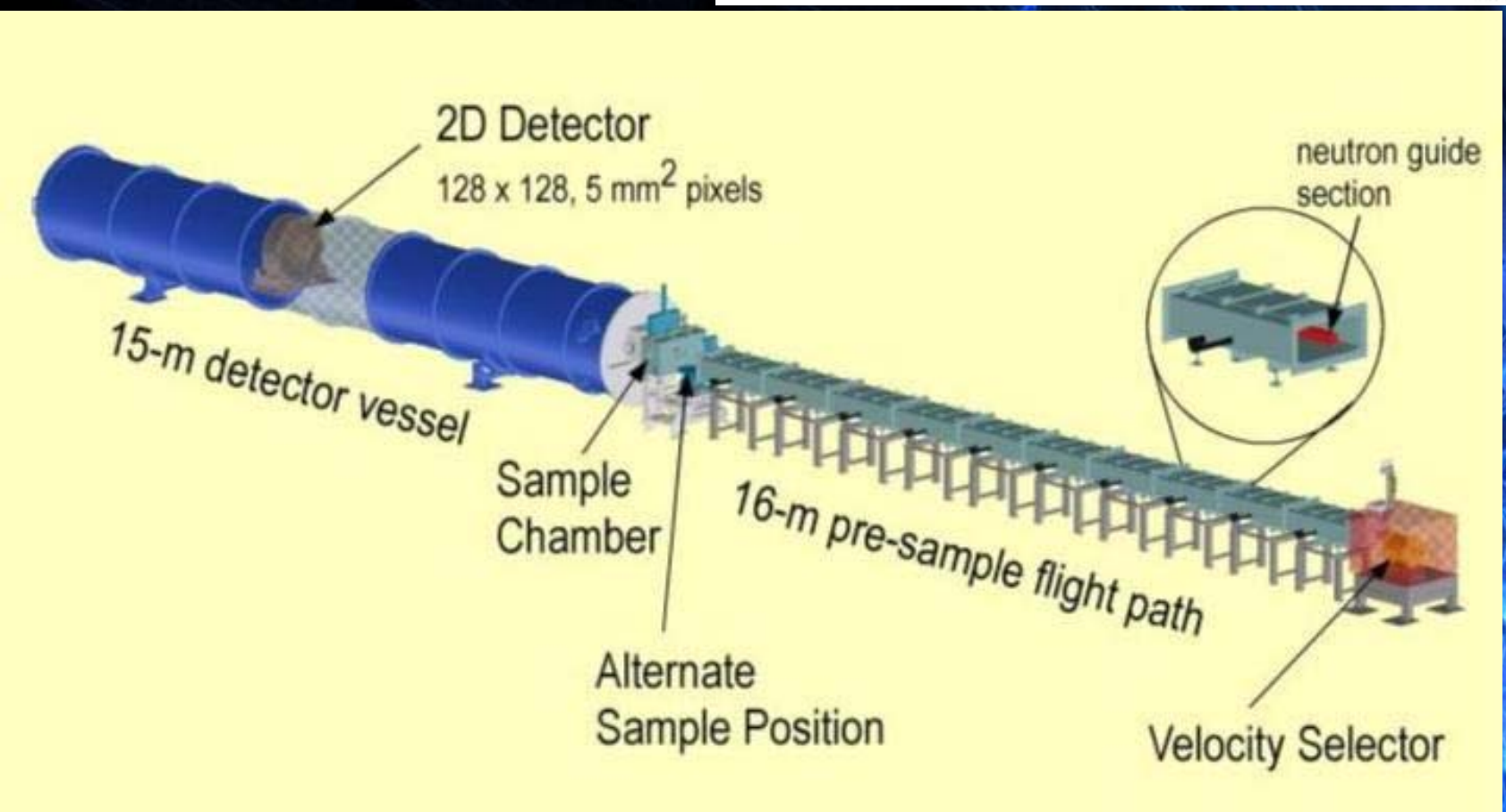
Elemental Composition (outgassed)



H	3198
C	166000
O	43478
Na	270
Al	194793
Cd	6.5
Y	29
Pt	680
F	18935

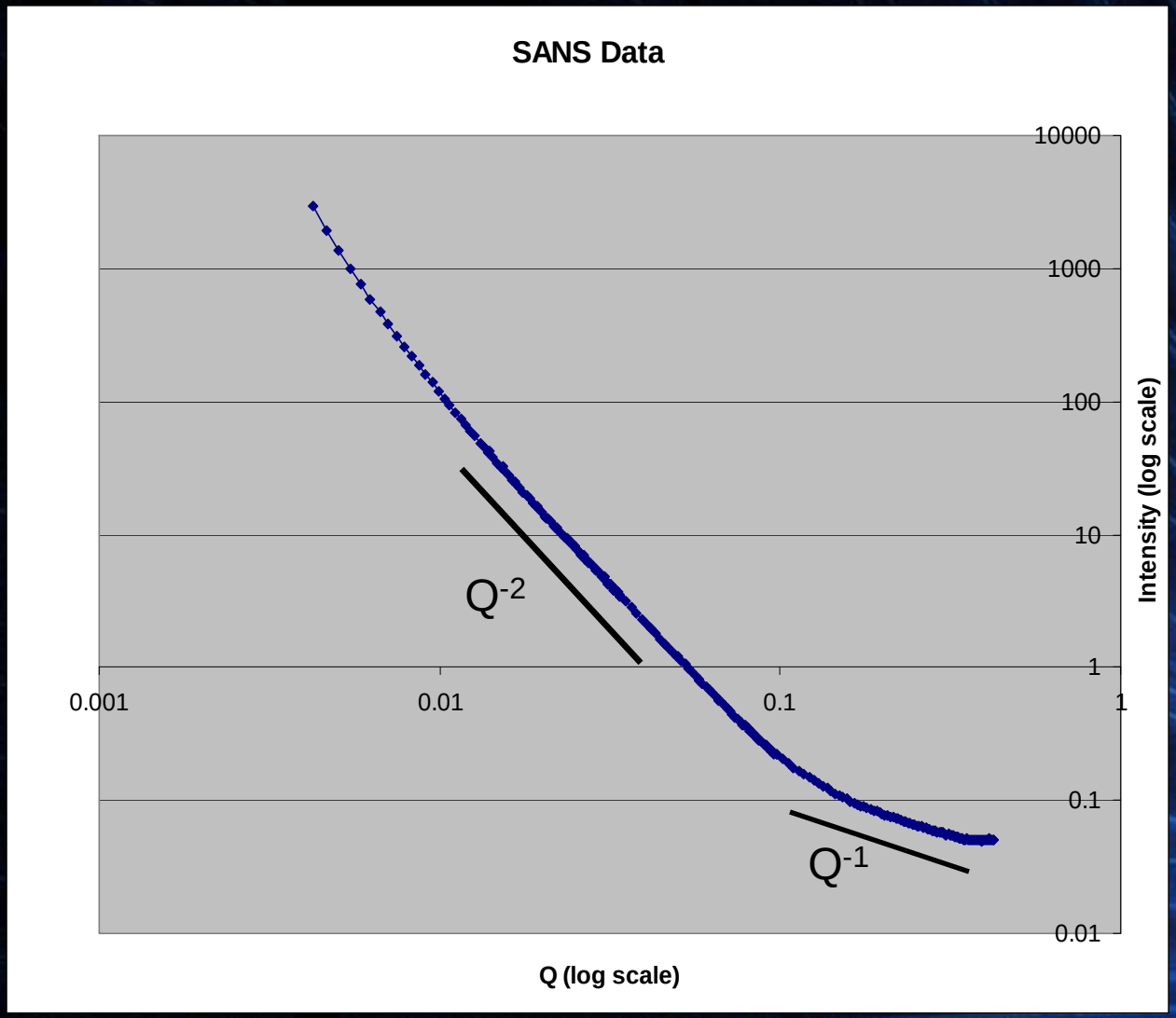
Small Angle Neutron Scattering





SANS Data

- Detects long range structure anomalies 10s-1000s Å
- Log log scale slopes of Q suggest different types of structures
- Consistent with results gained from other instruments

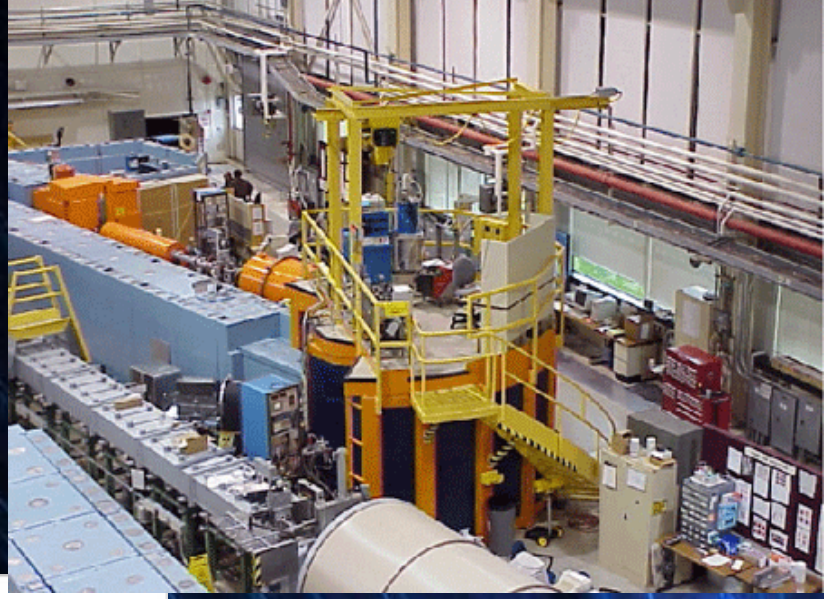


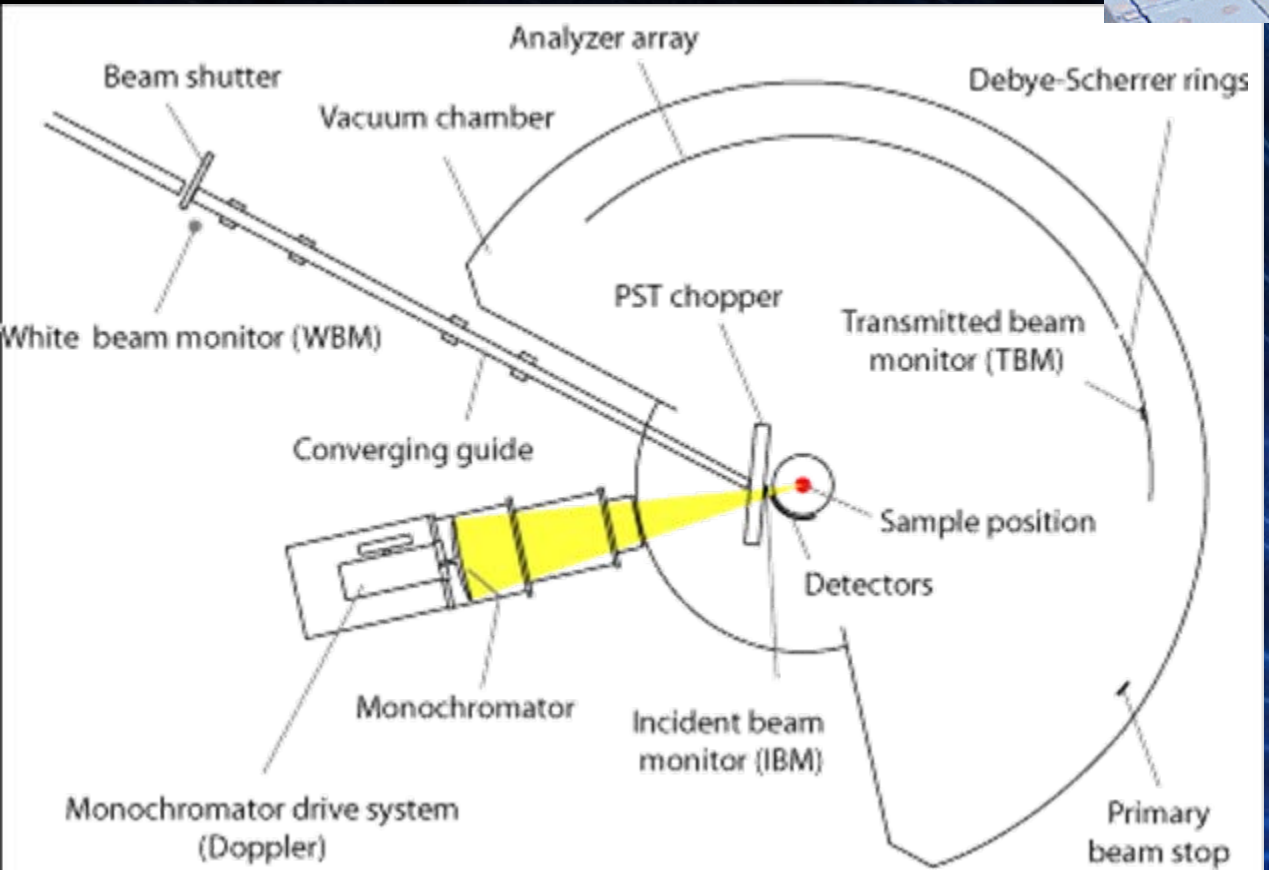
Q^{-1}= one dimensional pore

Q^{-2}= two dimensional pore (two planes)

Q^{-4}= smooth curved surface

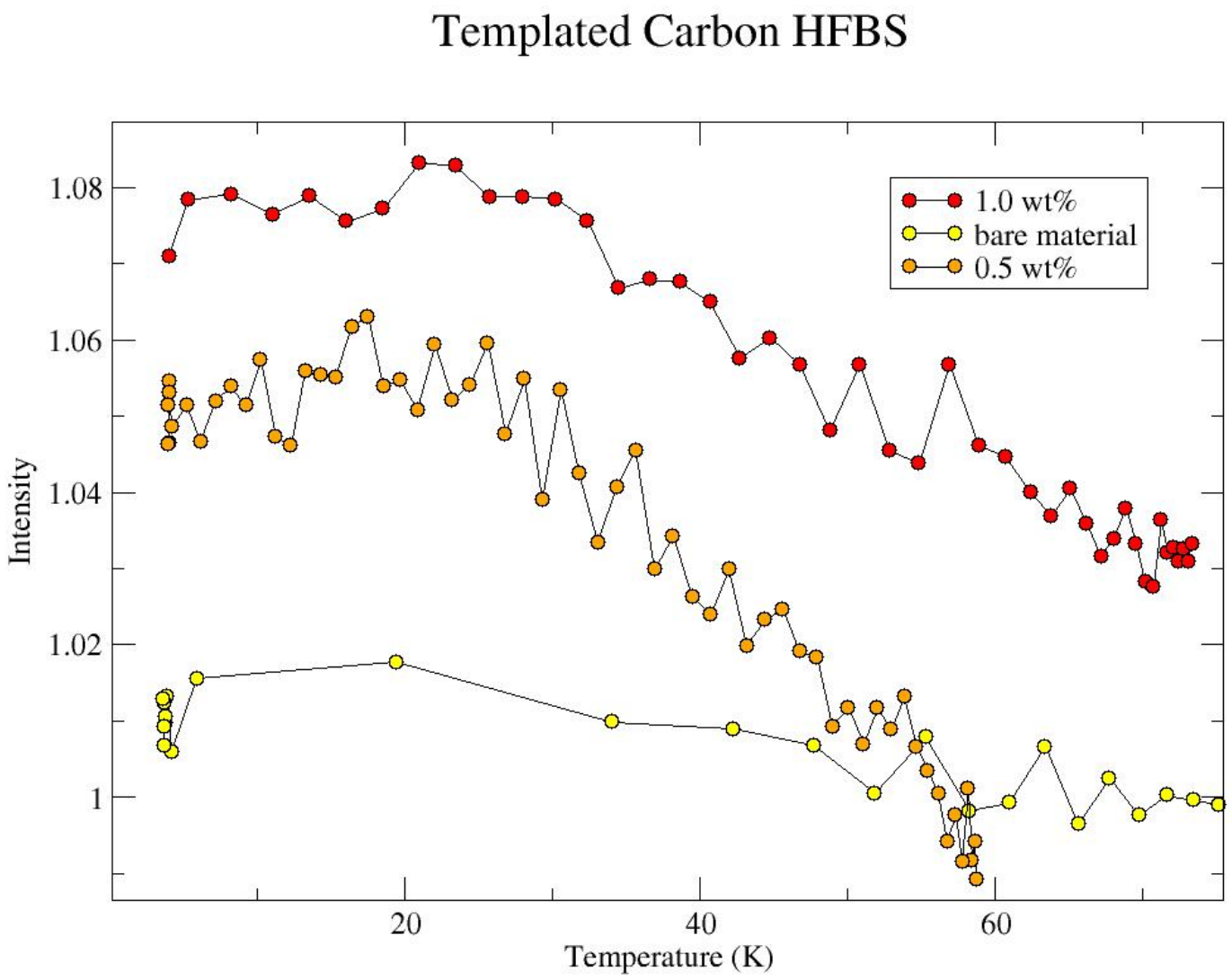
NG2 High Flux Backscattering



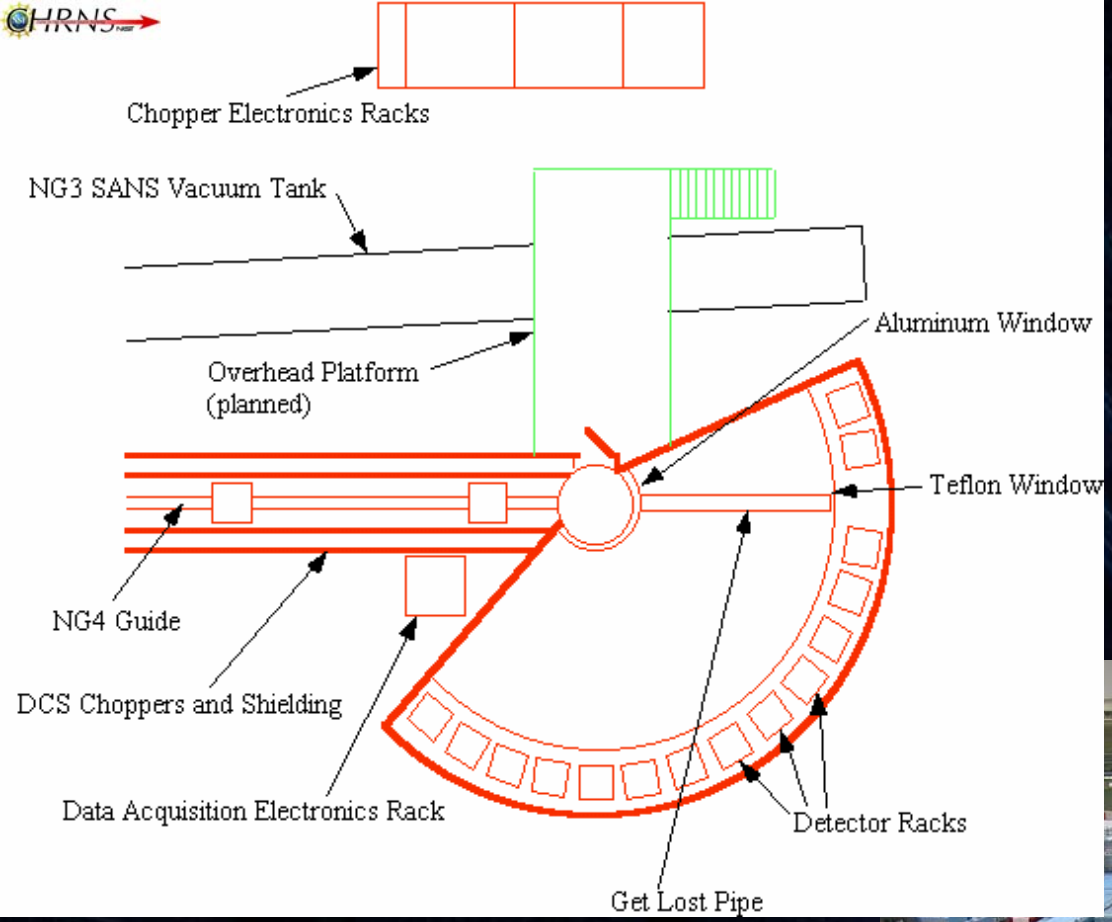


- High Flux
- High Resolution
- Small Q range
- Detects slow movements

HFBS Data

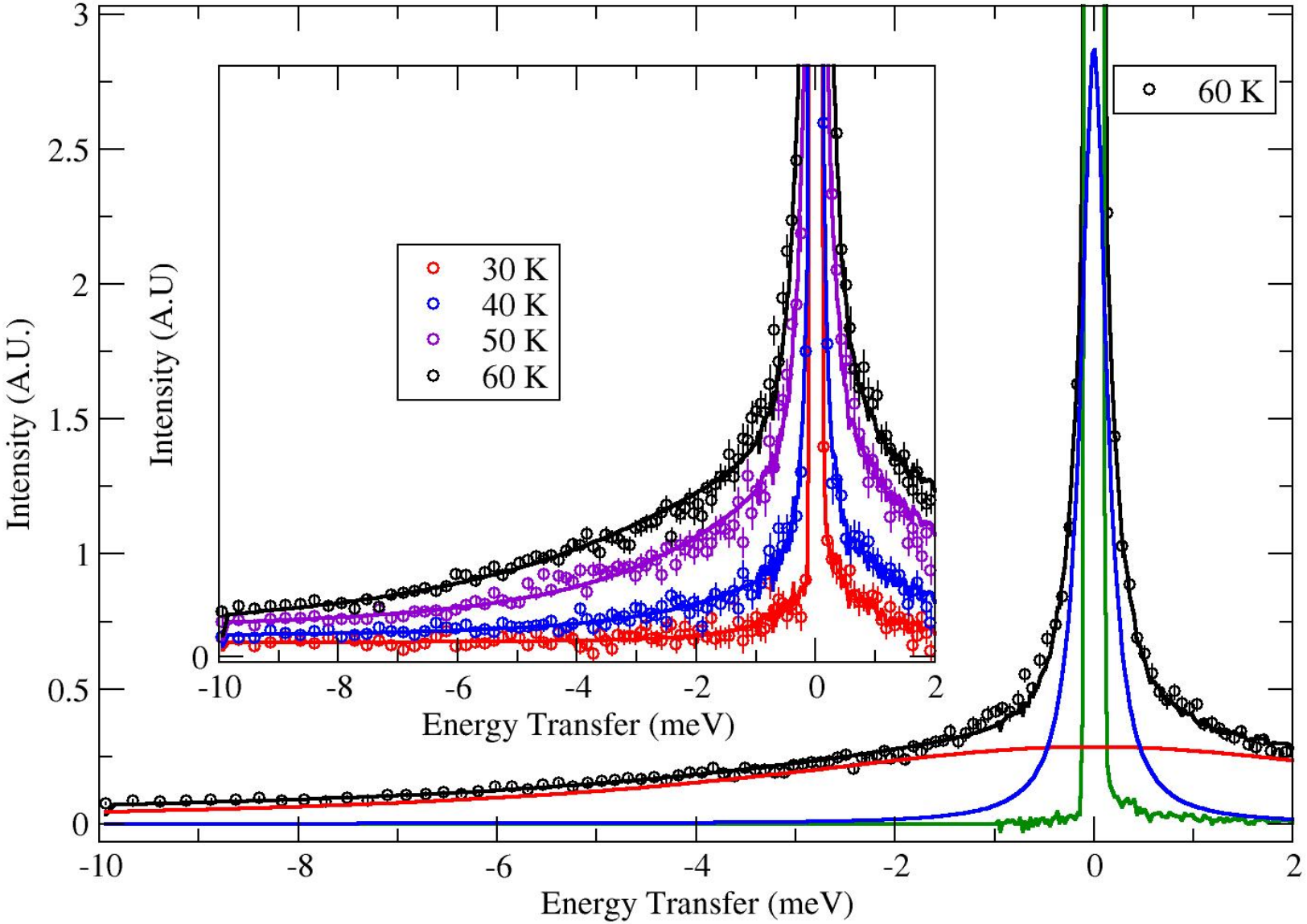

Templated Carbon HFBS
1.08
1.06
1.04
1.02
1
Intensity
20
40
60
Temperature (K)
1.0 wt%
bare material
0.5 wt%

NG4 Disk Chopper Spectrometer

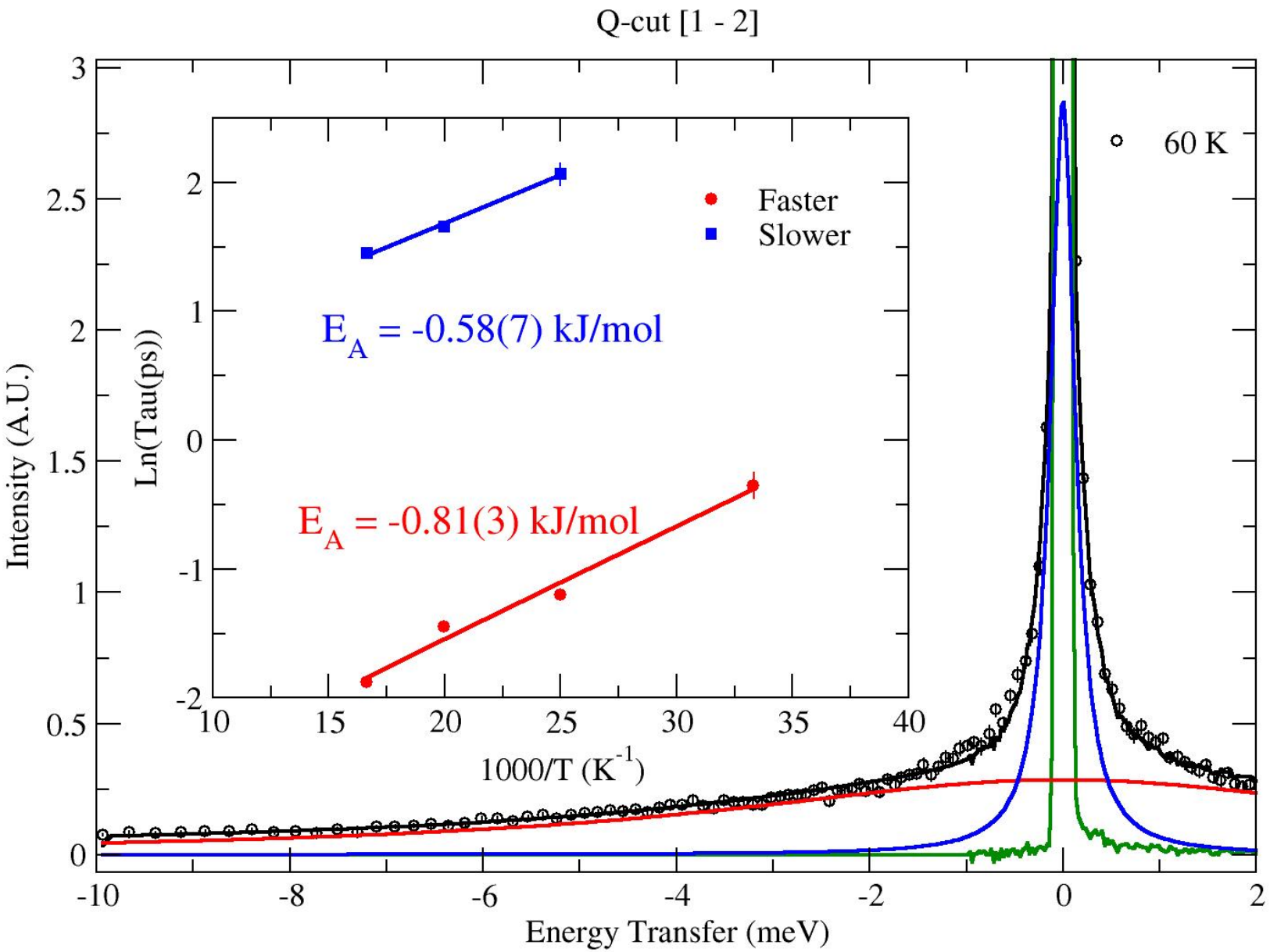


- High Flux
- High Q
- Low resolution
- Detects fast and slow hydrogen movements

0.5 wt% H_2 in Na-Y Templated carbon



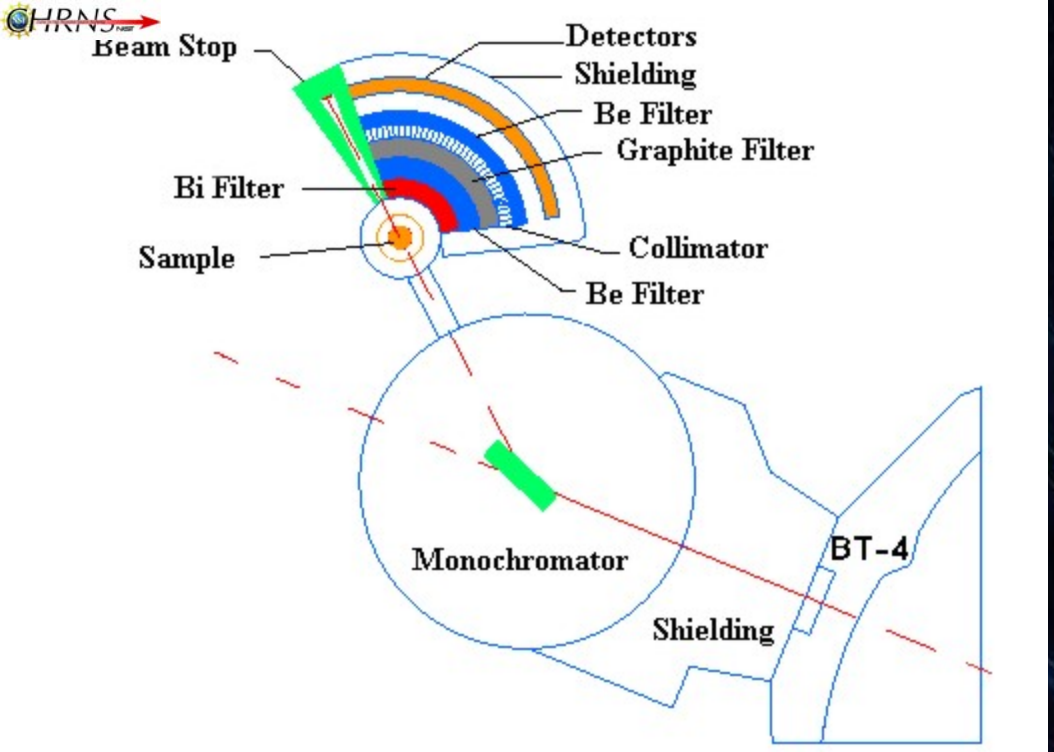
0.5 wt% H_2 in Na-Y Templated carbon



Additional Analysis

- Fits
  - 10K resolution (delta)
  - Lorentzian (wide)
  - Lorentzian (thin)
  - Flat background
- Wide lorentzian corresponds with fast movement
- Thin corresponds with slow movement

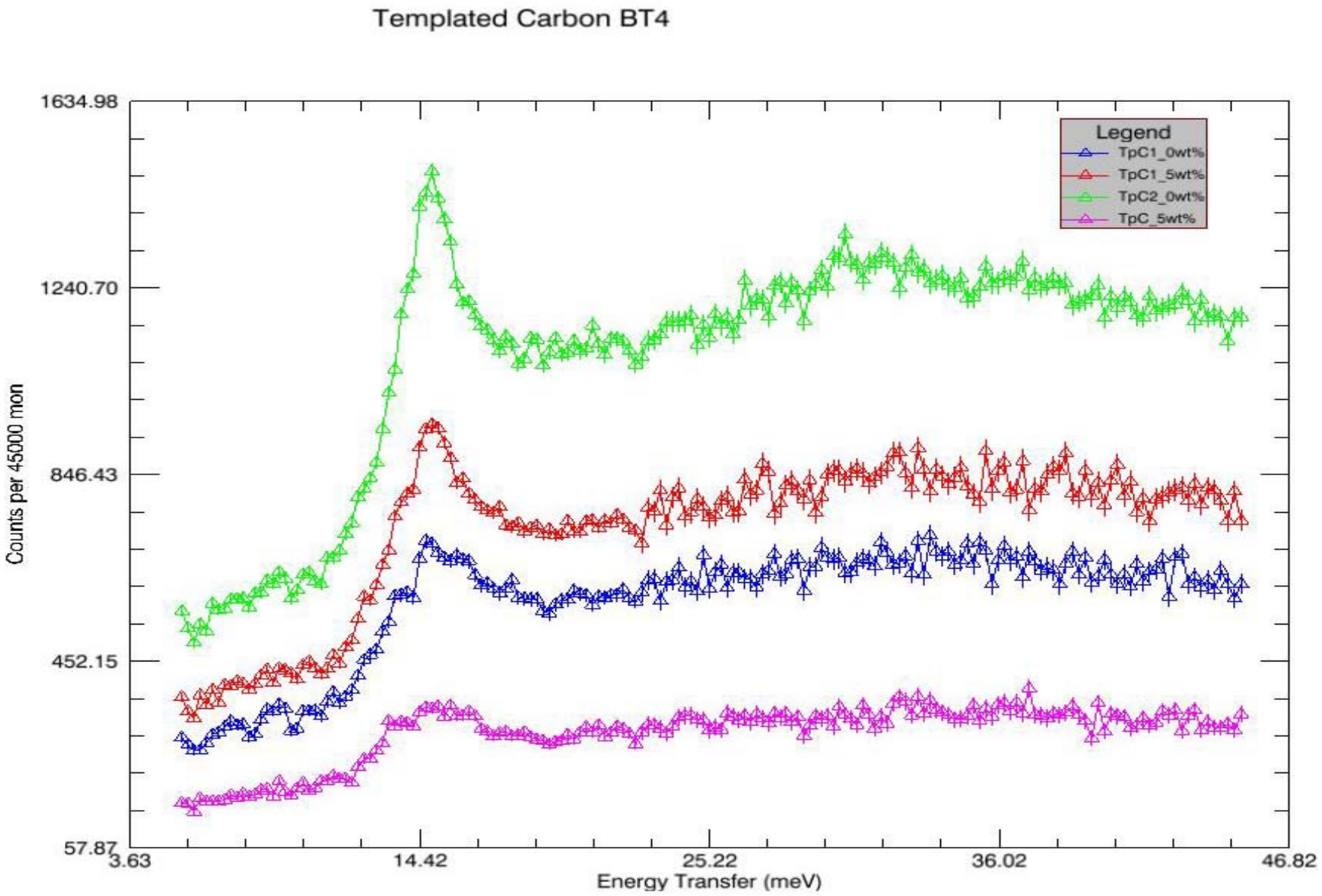
- Activation energy = .81 kJ/mol
- Thin Lorentzian = .58 kJ/mol
- Compares to
  - nanotubes= .37 kJ/mol
  - Solid H_2= 1.9 kJ/mol
  - Liquid H_2= .37 kJ/mol
  - Zeolite 13X= .515 - 1.99 kJ/mol
  - XC-72= 1.03 kJ/mol



BT4 Filter Analyzer Spectrometer

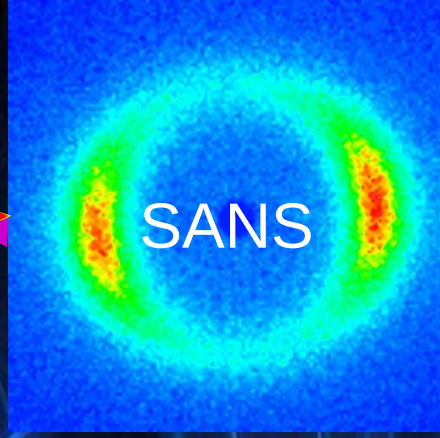
BT4 Data

- Quantum J=0-1 peak @14.7 meV
- Broad recoil
- H_2 being knocked off of sites by incident neutrons
- Background subtracted (only hydrogen)

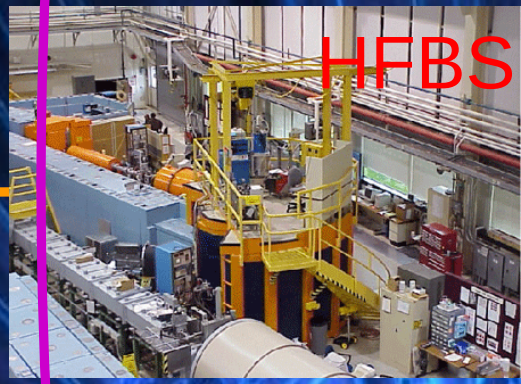


PGAA

$\gamma\Gamma$



Quantachrome



And it was the best summer ever!


CHRNS
NSF
Center for High Resolution Neutron Scattering
NIST