INTRODUCTION TO NEUTRON SCATTERING

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-- Why Use Neutrons?
-- Neutron Sources
-- Continuous *vs* Time-of-Flight
-- Neutron Sources in the US
-- The NIST Neutron Scattering Facilities
-- Neutron interactions
-- Elastic *vs* Inelastic Scattering
-- Coherent and Incoherent Scattering
-- Neutron Scattering Lengths and Contrast Factors
-- Introduction to SANS

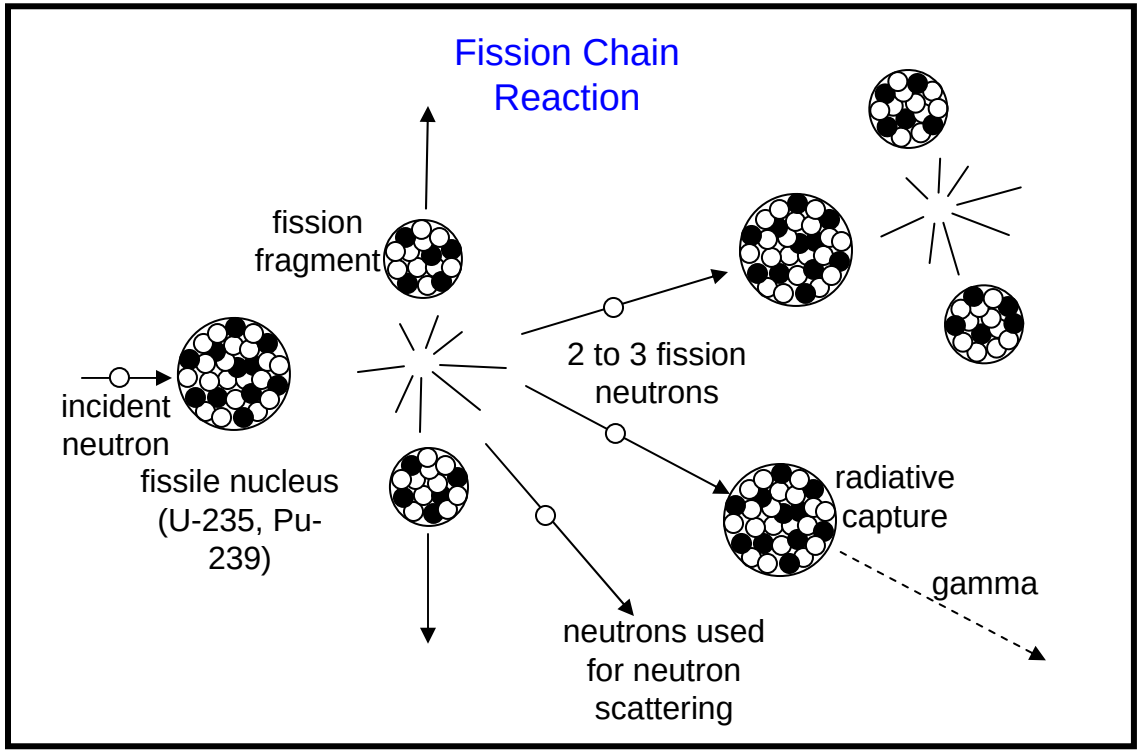
WHY USE NEUTRONS?

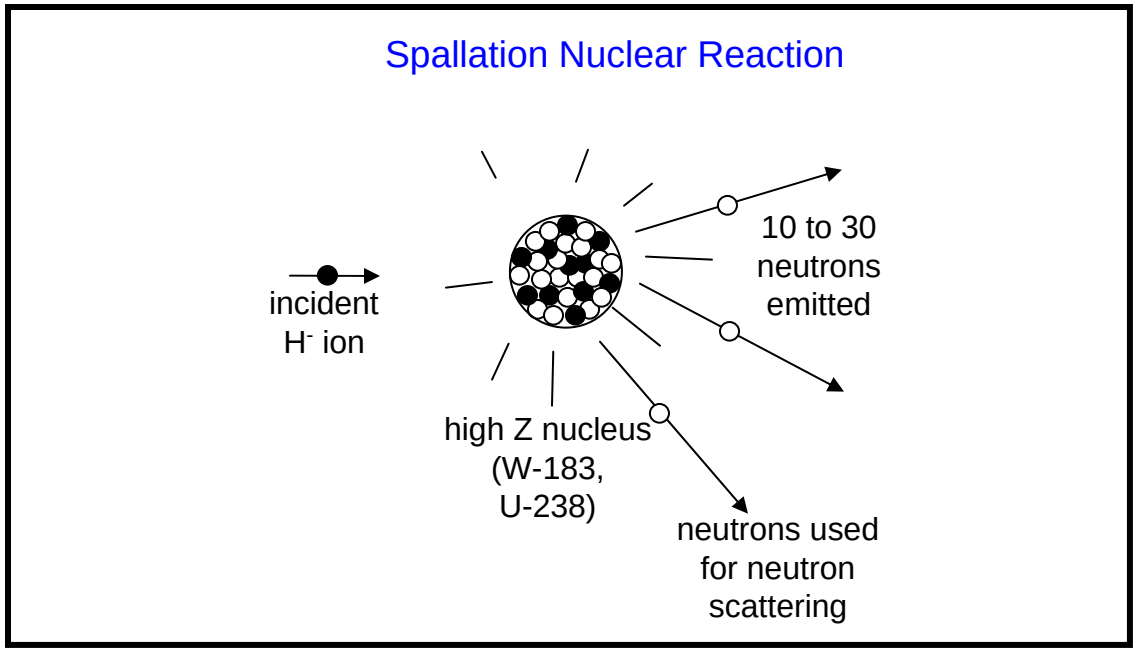
-- Neutrons interact through short-range nuclear interactions. They have no charge and are very penetrating and do not destroy samples.

-- Neutron wavelengths are comparable to atomic sizes and interdistance spacings.

-- Neutrons interactions with hydrogen and deuterium are widely different making the deuterium labeling method an advantage.

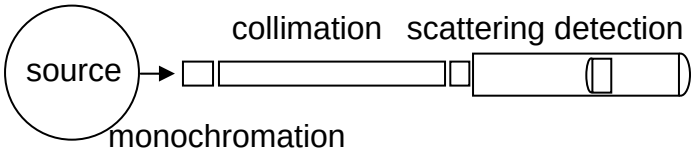
NEUTRON SOURCES

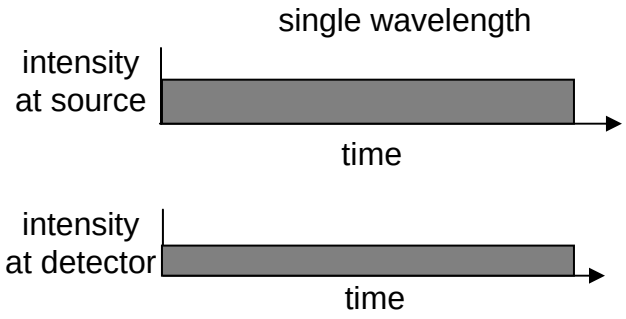




CONTINUOUS VS TIME-OF-FLIGHT

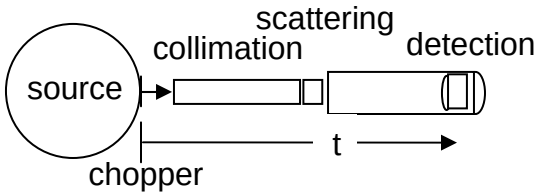
Continuous Reactors

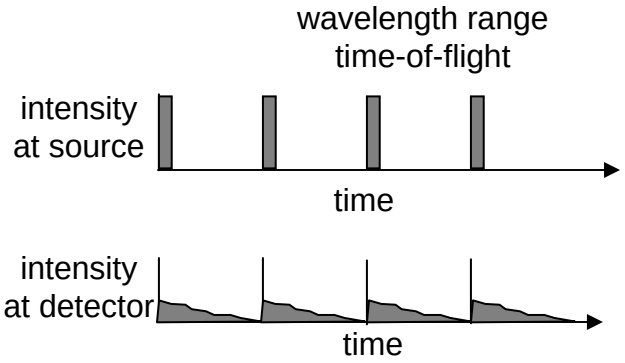




Measure some of the neutrons all of the time

Pulsed Sources





Measure all of the neutrons some of the time

NEUTRON SOURCES IN THE US

Continuous Sources:

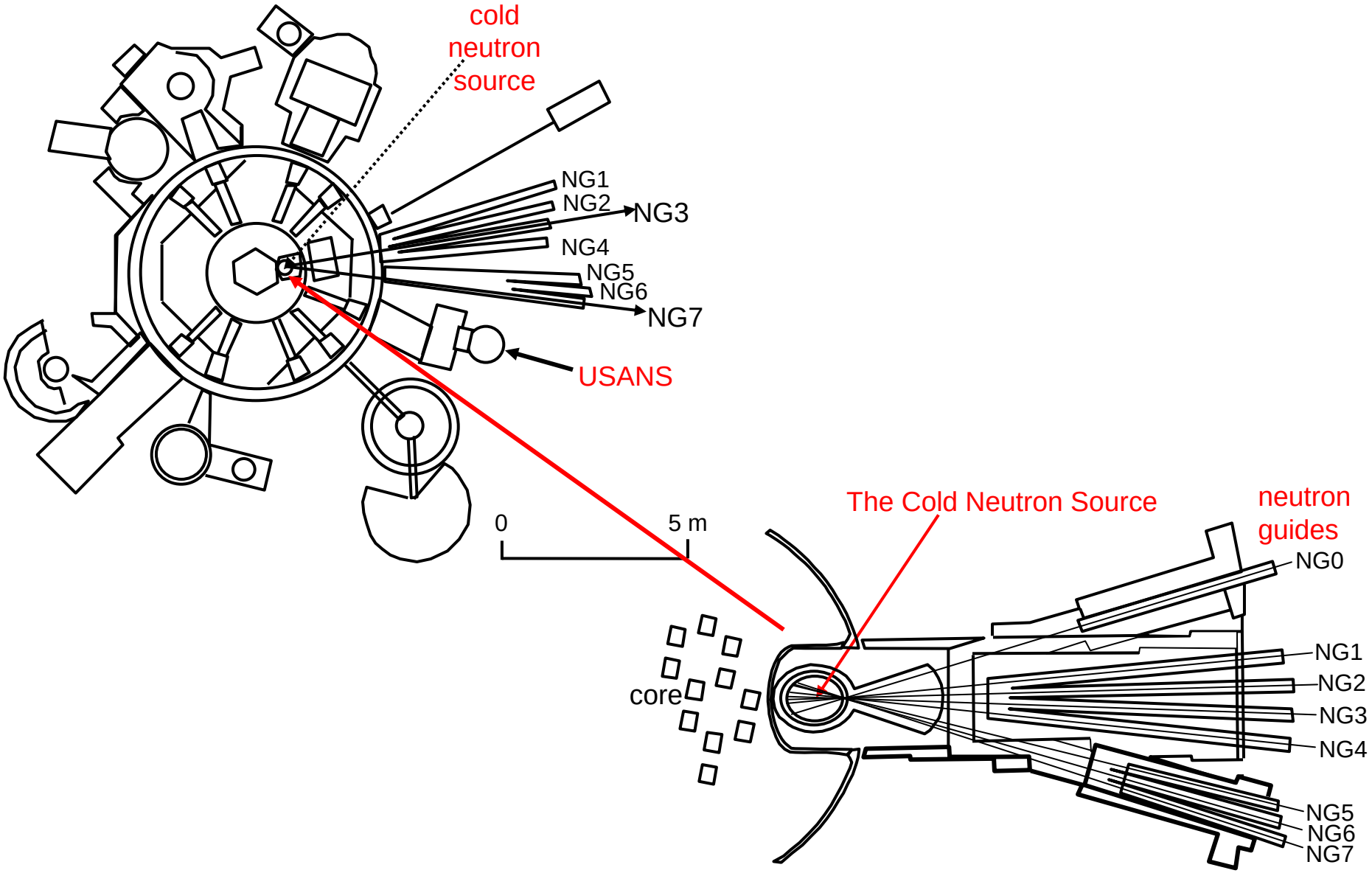
-- **HFIR**-**Oak Ridge** National Laboratory. http://neutrons.ornl.gov.
-- **NIST**-National Institute of Standards and Technology. http://www.ncnr.nist.gov.

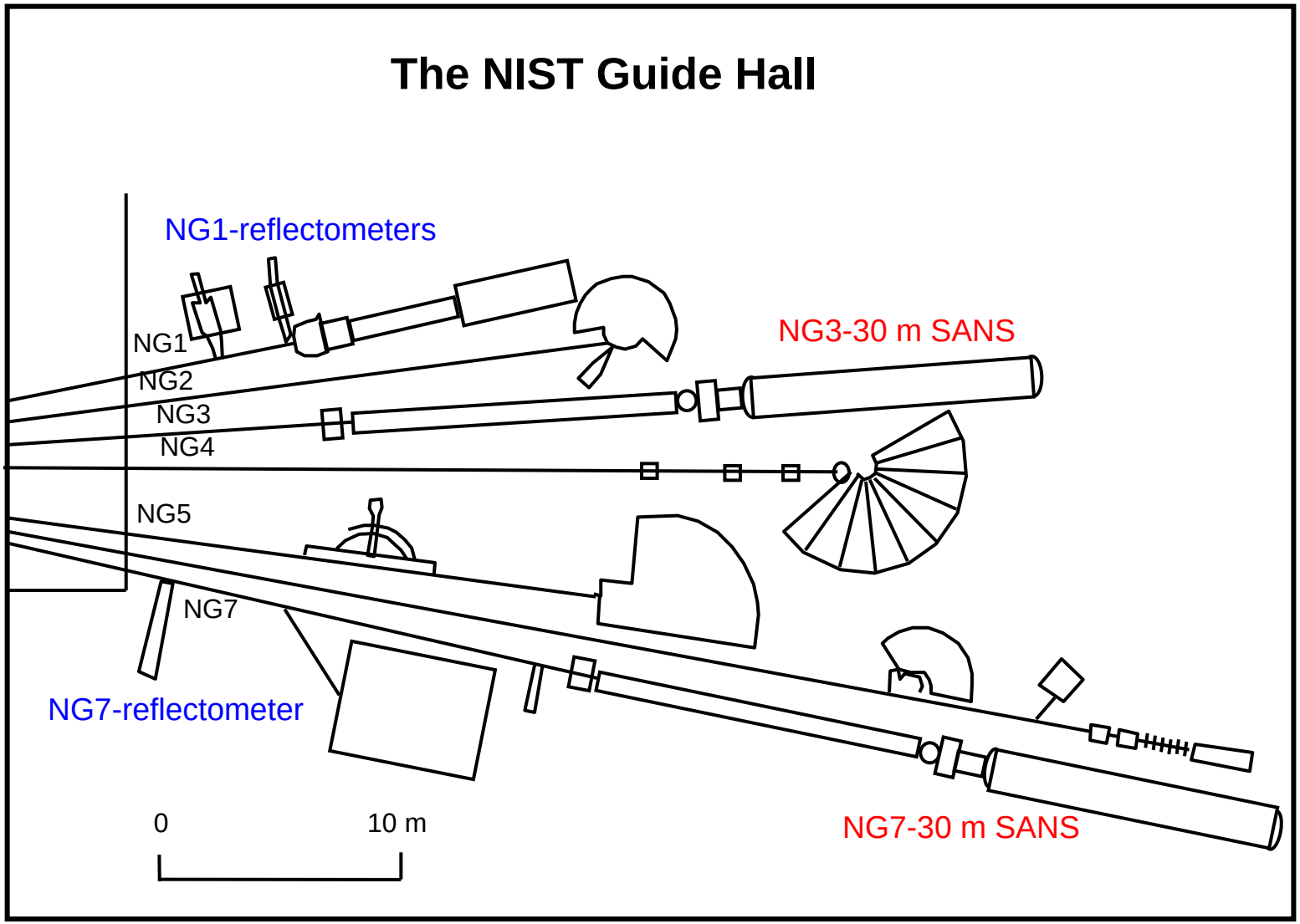
Pulsed Sources:

-- WNR/PSR LANSCE (**Los Alamos**). http://lansce.lanl.gov
-- **SNS** (**Oak Ridge** National Lab). http://www.sns.gov.

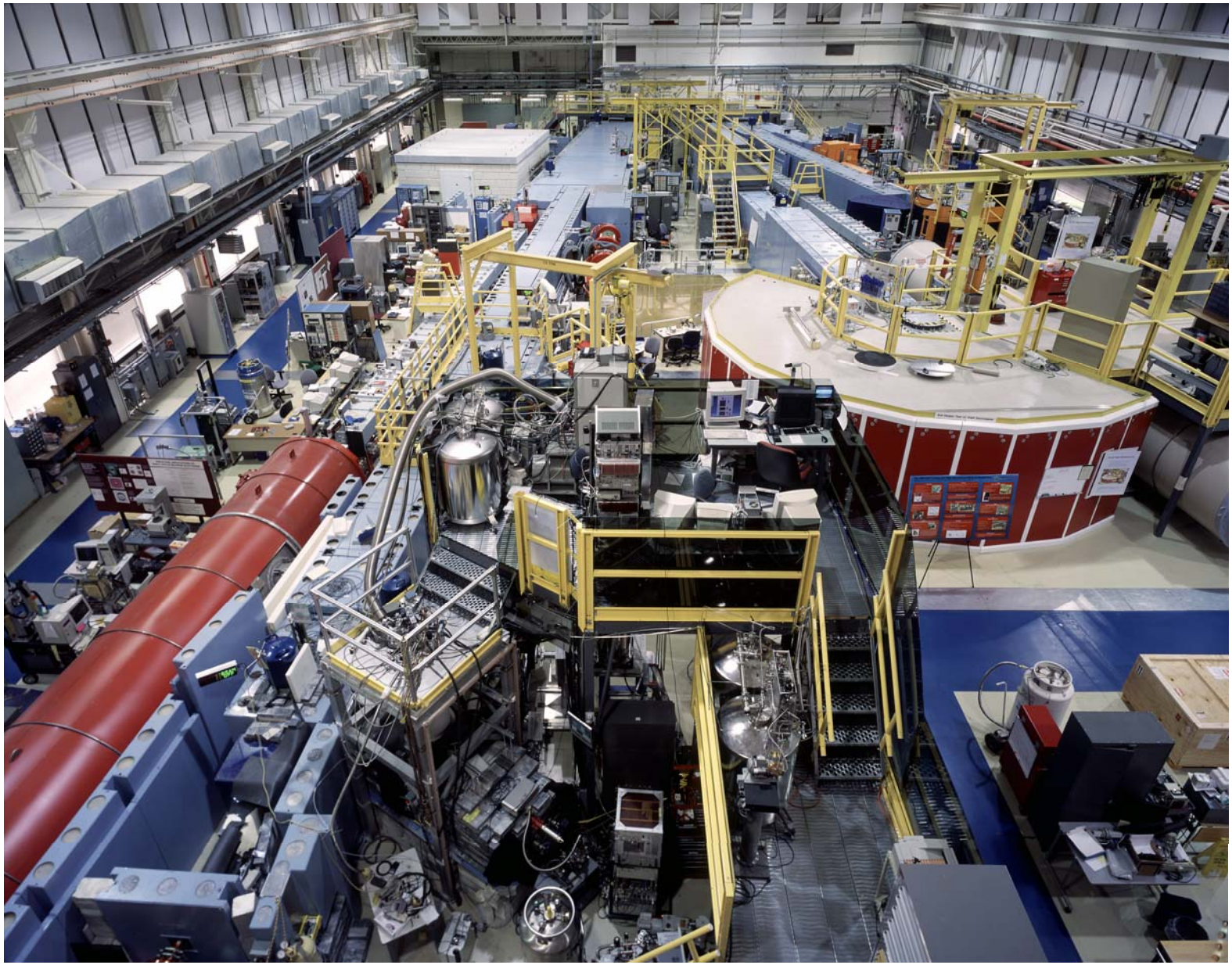
NIST Thermal Instruments

THE NIST NEUTRON SOURCE

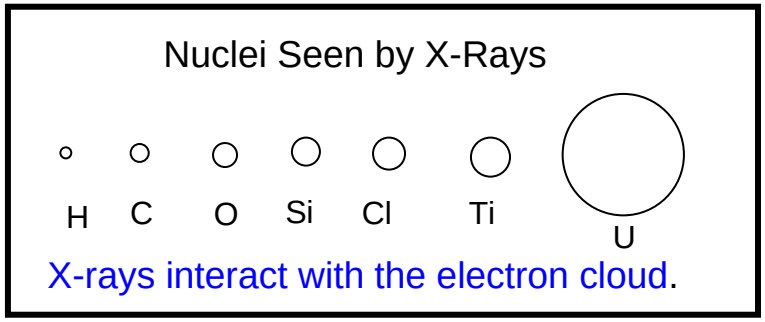


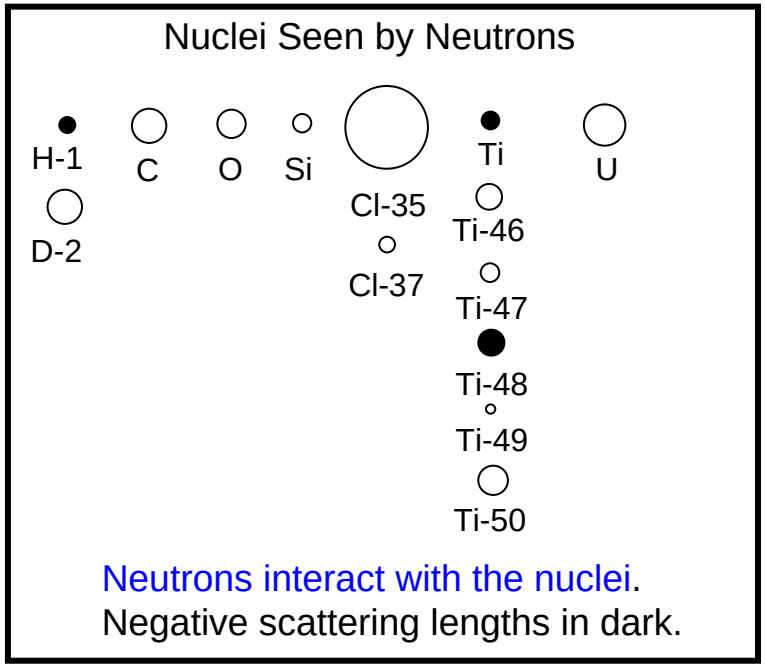

The NIST Guide Hall
NG1-reflectometers
NG1
NG2
NG3
NG4
NG3-30 m SANS
NG5
NG7
NG7-reflectometer
0
10 m
NG7-30 m SANS

The NIST Guide Hall

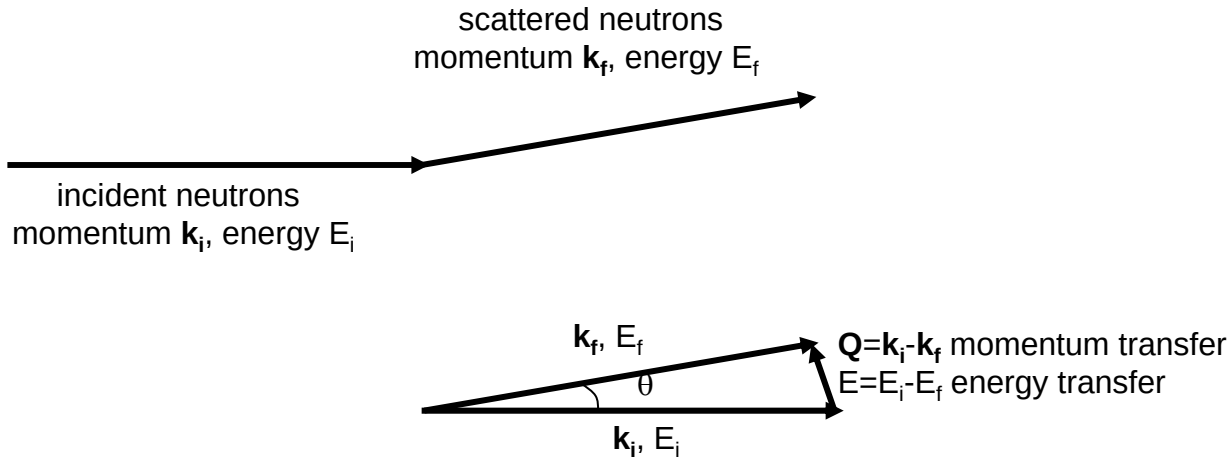


NEUTRON INTERACTIONS





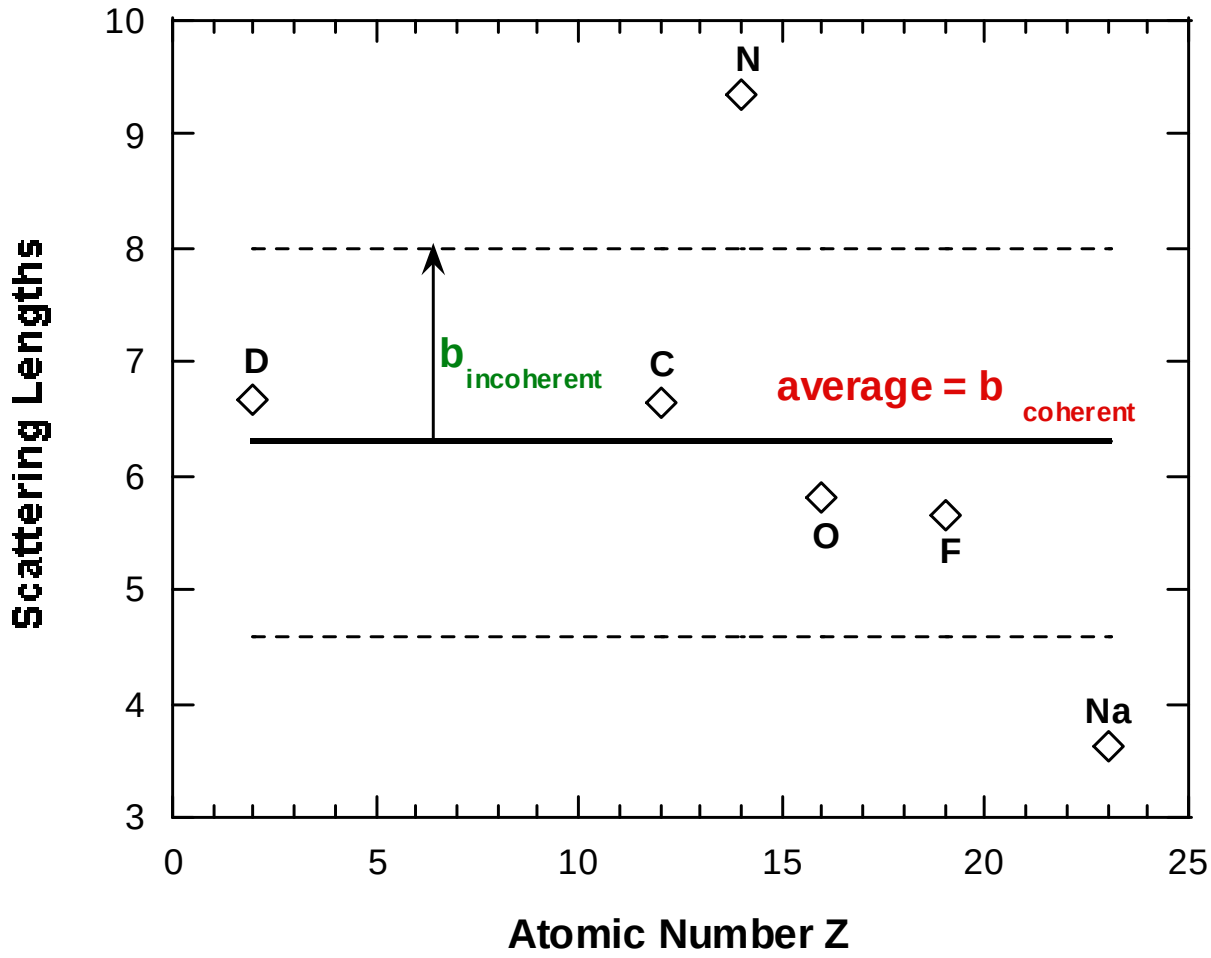
ELASTIC *vs* INELASTIC NEUTRON SCATTERING



Elastic scattering corresponds to E=0. Investigate structures.

SANS and NR are elastic scattering techniques.

COHERENT AND INCOHERENT SCATTERING



NEUTRON SCATTERING LENGTHS AND CROSS SECTIONS

	Scattering Lengths		Scattering Cross Sections		
	Coherent	Incoherent	Coherent	Incoherent	Absorption

Element	b_c Fermi	b_i Fermi	σ_c Barn	σ_i Barn	σ_a Barn
H-1	-3.739	25.278	1.757	80.30	0.333
D-2	6.671	4.04	5.592	2.05	0.000
C-12	6.646	0	5.550	0.001	0.003
N-14	9.36	2.0	11.01	0.50	1.90
0-16	5.803	0	4.232	0.000	0.000
F-19	5.654	0	4.232	0.001	0.000
Na-23	3.63	3.59	1.66	1.62	0.530

1 Fermi = 10^{-13} cm.
1 Barn = 10^{-24} cm^2.

Case of D_2O:

Mass m_{D2O} = 20 g/mole, Density d_{D2O} = 1.111 g/cm^3.
Specific Volume = $v_{D2O} = m_{D2O}/d_{D2O}$ = 18 cm^3/mole.
Scattering Length: $b_{D2O} = 2b_D+b_O = (2*6.671+5.803) *10^{-13} = 19.145*10^{-13}$ cm.
Scattering Length Density: $b_{D2O}/v_{D2O} = 1.064*10^{-13}$ cm^{-2}mole = $6.38*10^{-6}$ Å^{-2}.

Microscopic coherent scattering cross section $\sigma_c = 4\pi <b>^2$ units of barns.
Macroscopic coherent scattering cross section: $\Sigma_c = (N/V)\ \sigma_C$ units of cm^{-1}.

Contrast factor (mixture of A in B): $(b_A/v_A-b_B/v_B)^2$ in units of cm^{-4}.

Example of Poly(ethylene oxide)/Deuterated Water (hPEO/D_2O) Solution:

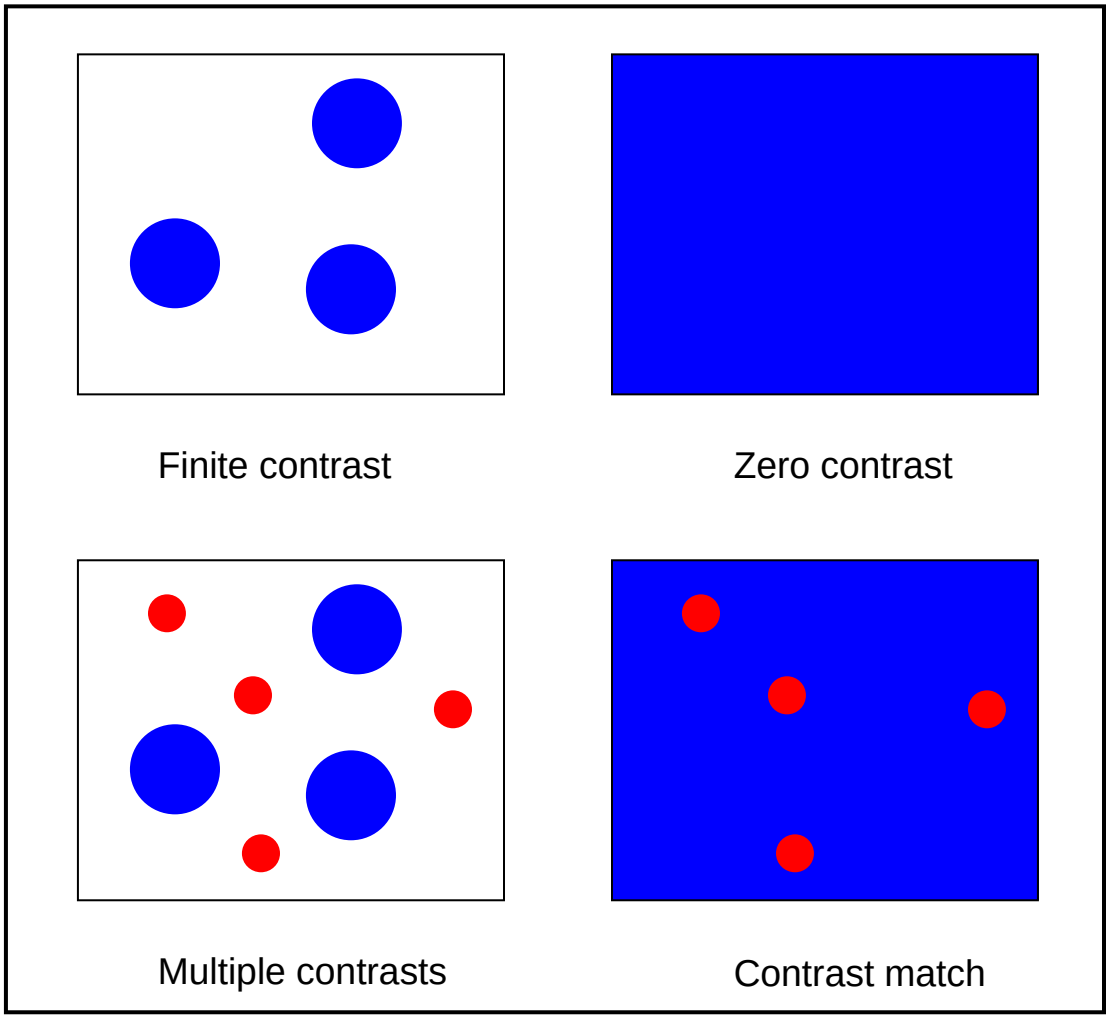
hPEO: C_2H_4O, $b_{hPEO} = 4.139*10^{-13}$ cm, V_{hPEO} = 38.94 cm^3/mole
d-water: D_2O, $b_{D2O} = 19.14*10^{-13}$ cm, V_{D2O} = 18 cm^3/mole

Contrast factor: $(b_{hPEO}/v_{hPEO}-b_{D2O}/v_{D2O})^2N_{av}=5.498*10^{-3}$ mole/cm^4. N_{av} is Avogadro's #.

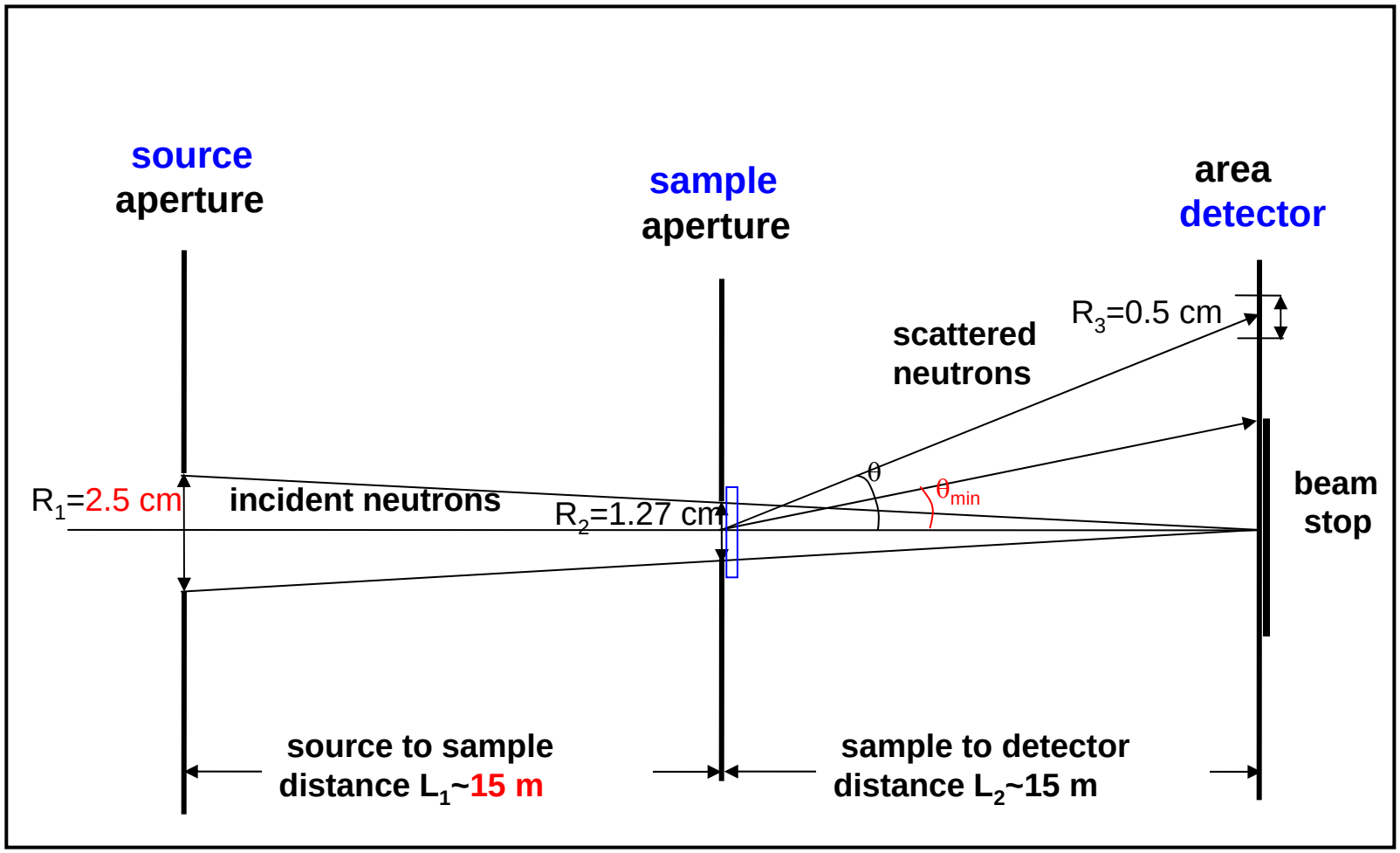
Online Scattering Length Density/Cross Section Calculator:

http://www.ncnr.nist.gov/resources/sldcalc.html

The Contrast Match Method

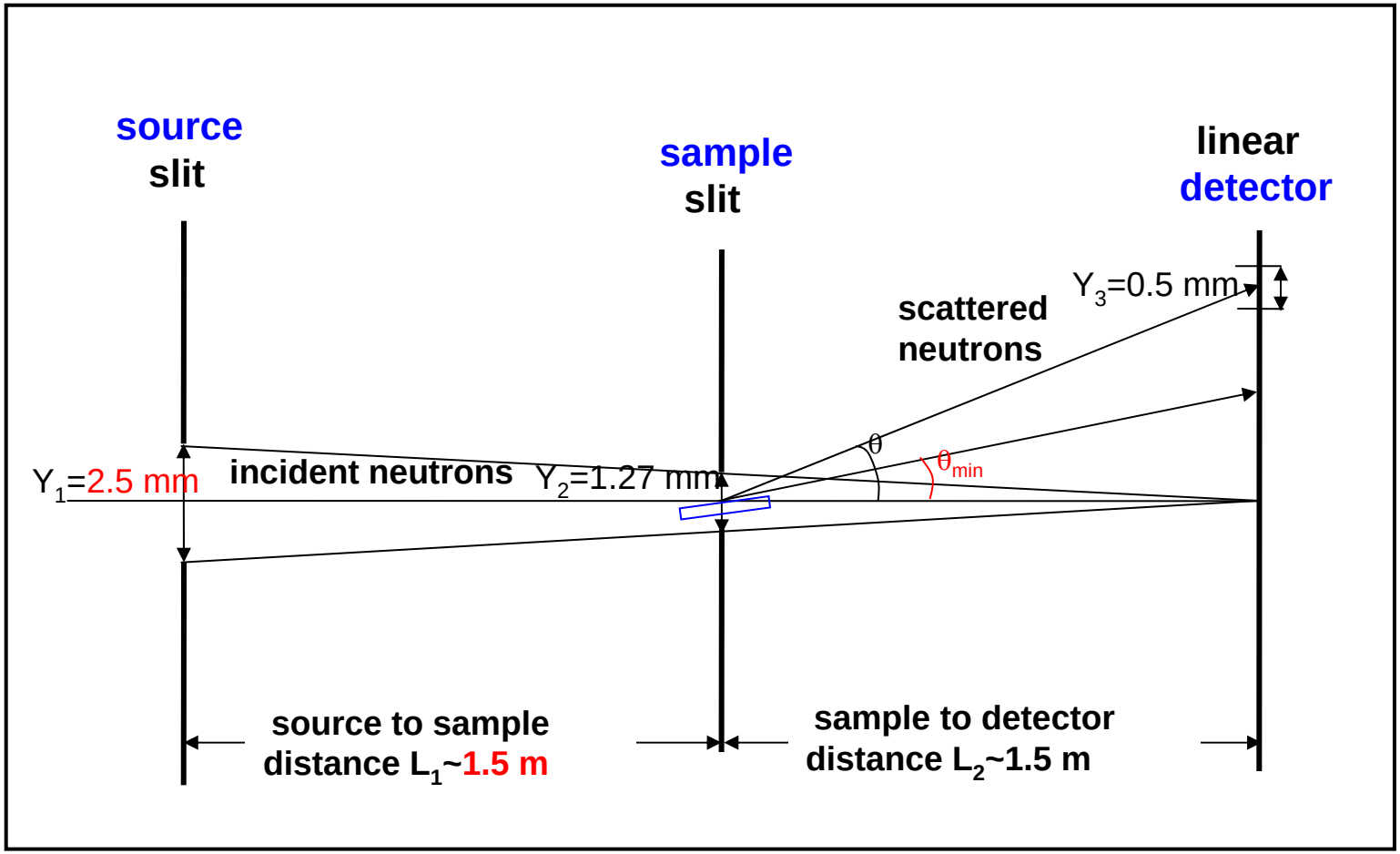


SANS GEOMETRY



$$\theta_{min} = (R_1+R_2)/L_1+R_2/L_2+R_3/L_2 \sim 3.7*10^{-3}\ \text{Rad} \sim 0.2^{o}$$

REFLECTOMETRY GEOMETRY



$$\theta_{min} = (R_1+R_2)/L_1+R_2/L_2+R_3/L_2 \sim 3.7*10^{-3}\ \text{Rad} \sim 0.2^{o}$$