VIRTUAL LEARNING RESOURCES FOR EDUCATION AND TRAINING IN NEUTRON SCATTERING

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Pat Clancy Group

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2022 CAP Congress

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[1] McMaster University, [2] Mystic Mill Games, [3] Canadian Nuclear Laboratories, [4] University of Windsor, [5] University of Toronto

MOTIVATION

- Neutron scattering is a powerful tool for materials research

- McMaster Nuclear Reactor (MNR) is Canada's only source of neutron beams for material research

- 5 MW open-pool reactor & multipurpose research reactor:

  - **Neutron scattering**

  - Neutron irradiation

  - Medical isotope production

  - Neutron radiography

  - Prompt gamma/neutron activation

  - Positron beam production
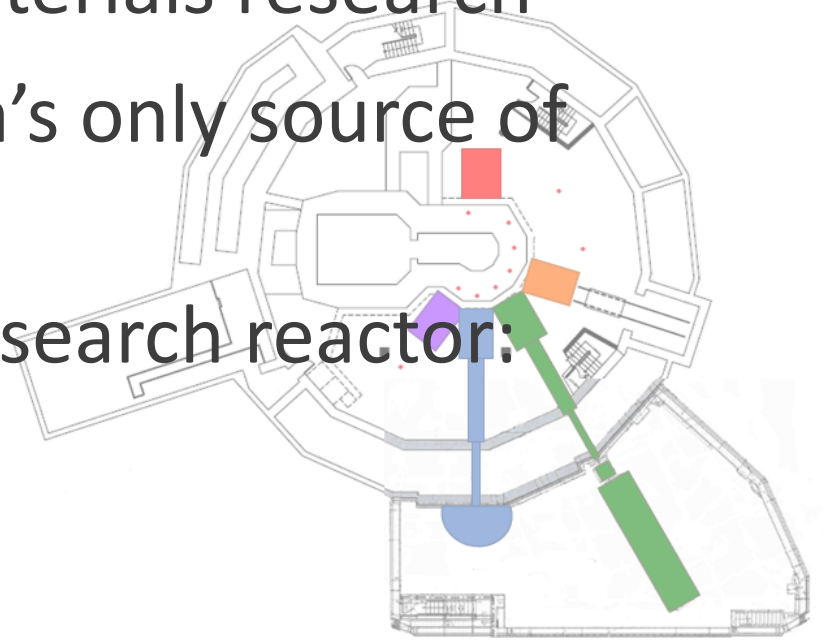
MOTIVATION

- Challenges for neutron scattering education and training:
  - Limited access
  - Difficult learning environment
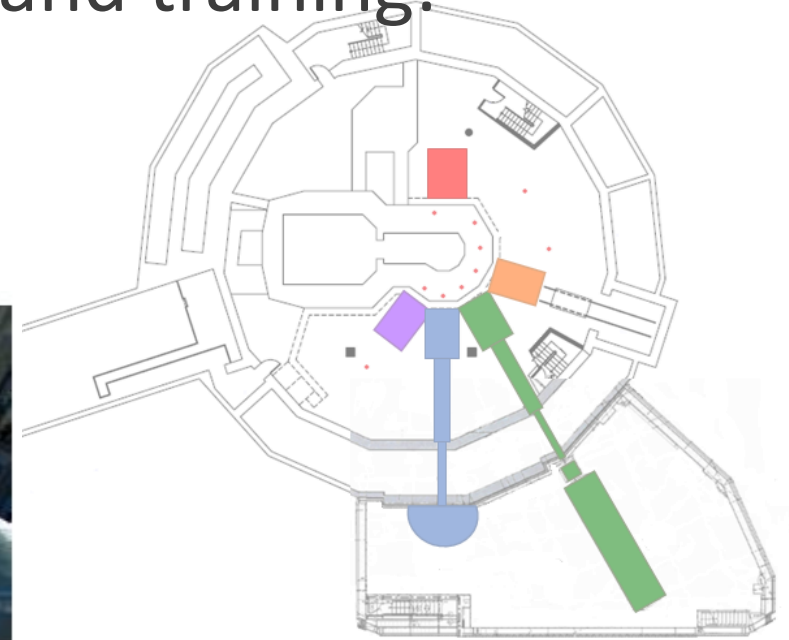
Virtual learning resources for education and training in neutron scattering techniques and applications

- June 2021 – Present

I)   Video Series

II)   Research Applications Videos

III) Virtual Lab Experiments

IV)   MAD and MacSANS Simulation

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I) VIDEO SERIES

- 5-10 min introductory videos for first-year university students in physics

- Introduce neutron scattering using first-year level physics

- Can be used individually or as add-on material for introductory physics courses

Module 1:
Neutron Scattering: Applications of Elastic and Inelastic Collisions

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Neutrons can collide with the lattice and either GIVE or TAKE energy from the lattice's vibration, just like in an inelastic collision

atoms   atoms

electrons

spring constant between atoms
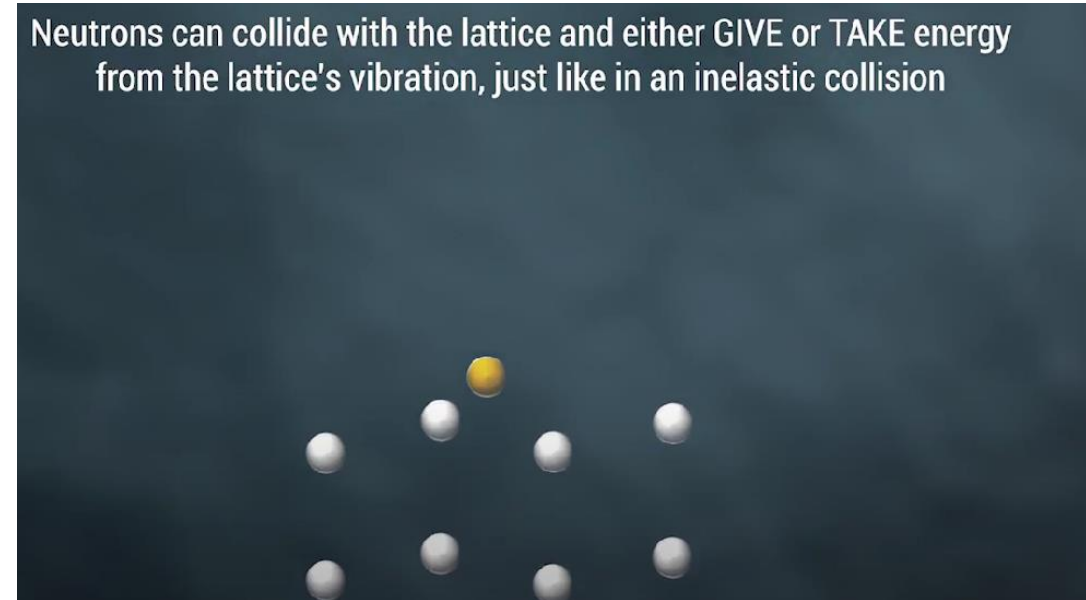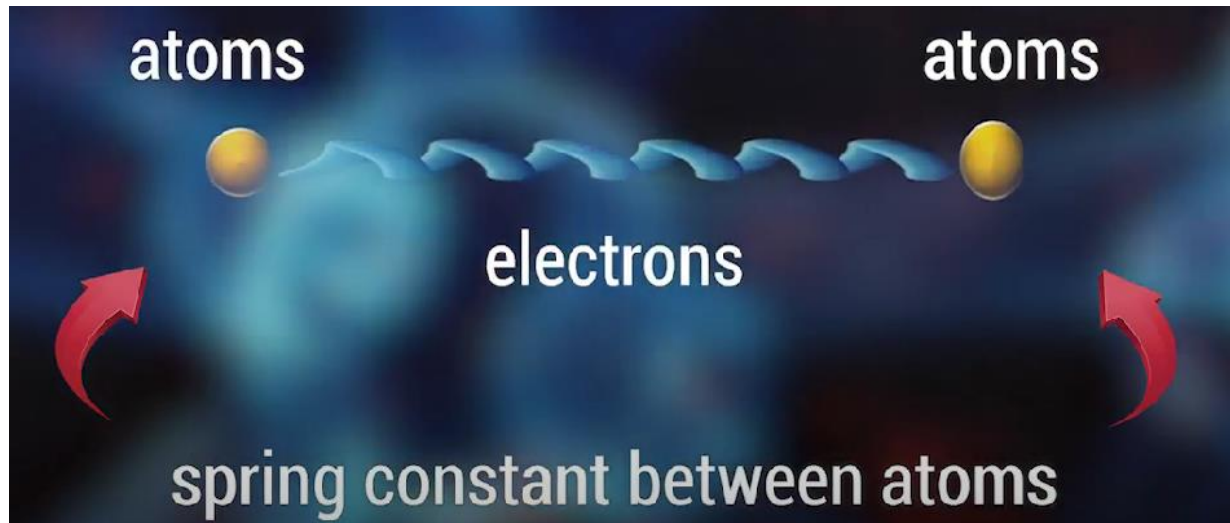
Module 2:
Structure: Particle-wave duality, Diffraction, Interference

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θ

d

$= d\cdot\sin\theta$

$= 2d\cdot\sin\theta$

θ
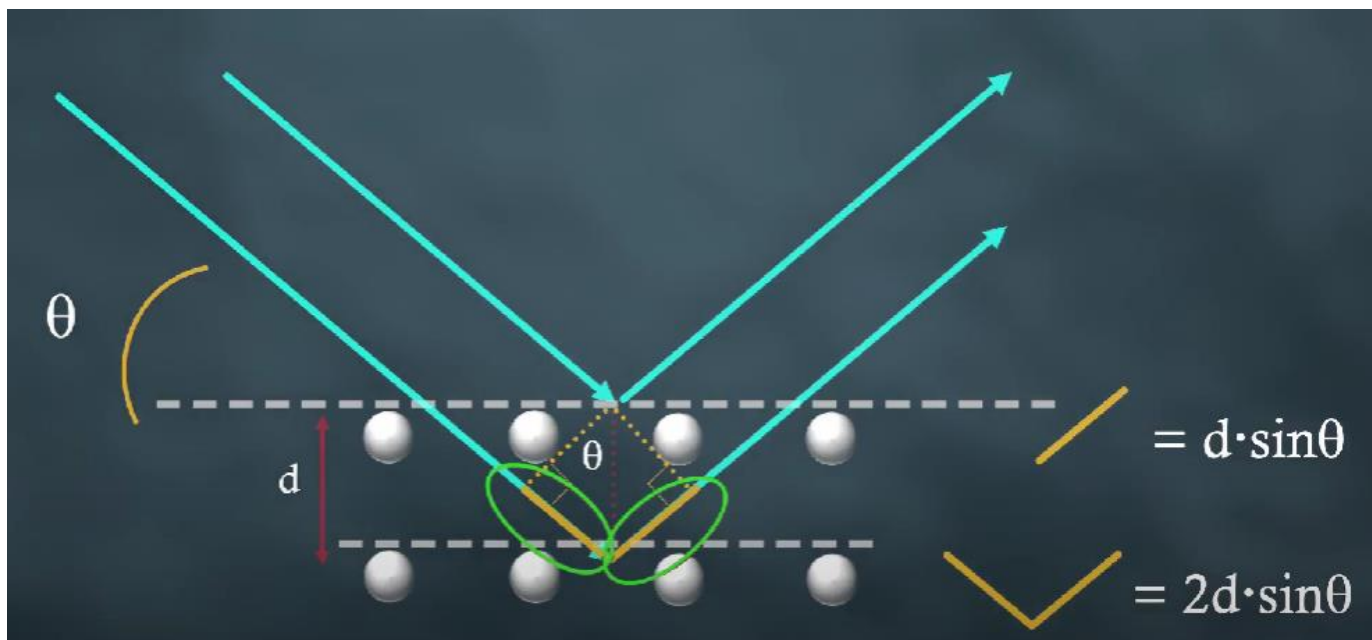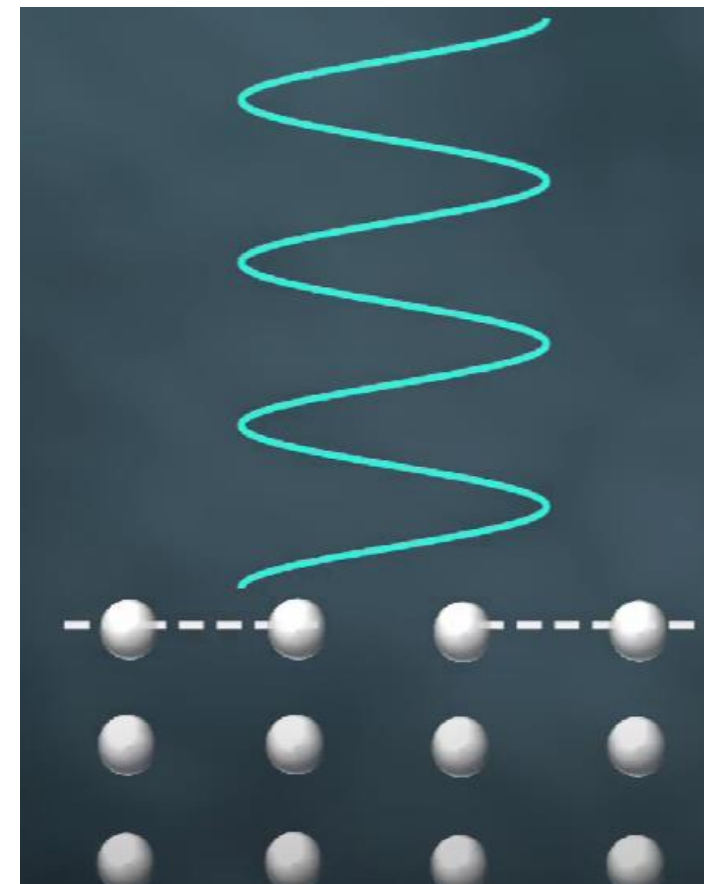
Extra pathlength = $2d\cdot\sin\theta$

$= n\cdot\lambda$ = constructive interference

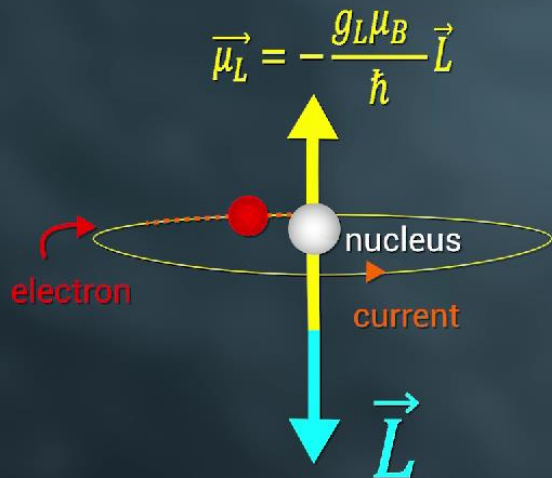Bragg's law of diffraction

Module 3:
Magnetic Neutron Scattering

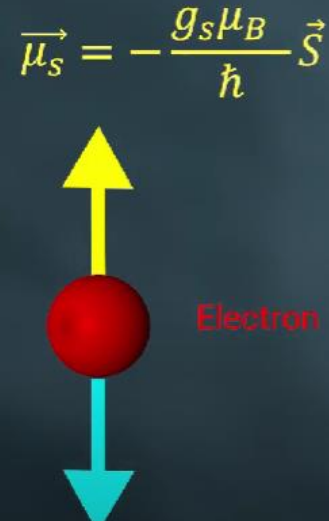McMaster University | SCIENCE Department of Physics & Astronomy

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Magnetic Ordering

- •Paramagnetic
- •Ferromagnetic
- •Antiferromagnet

Orbital Motion
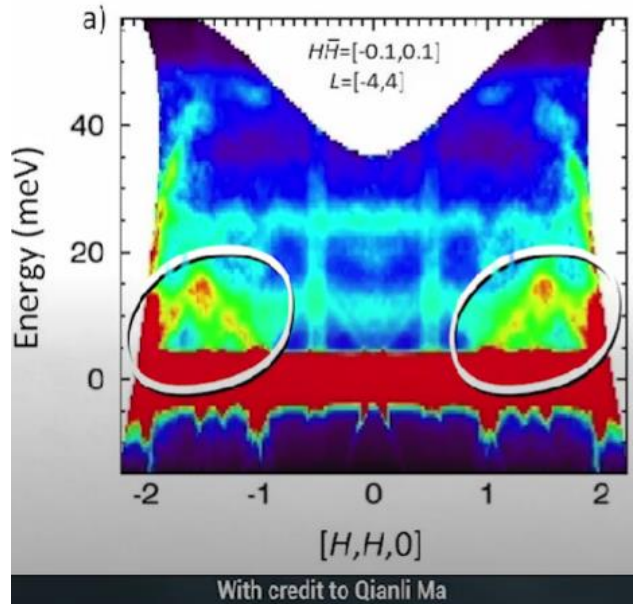
$$\vec{\mu_L} = -\frac{g_L \mu_B}{\hbar} \vec{L}$$

nucleus

electron

current

$$\vec{L}$$

Spin Motion

$$\vec{\mu_s} = -\frac{g_s \mu_B}{\hbar} \vec{S}$$

Electron

Nuclear Scattering

Neutrons

Detector

Nucleus

I) VIDEO SERIES

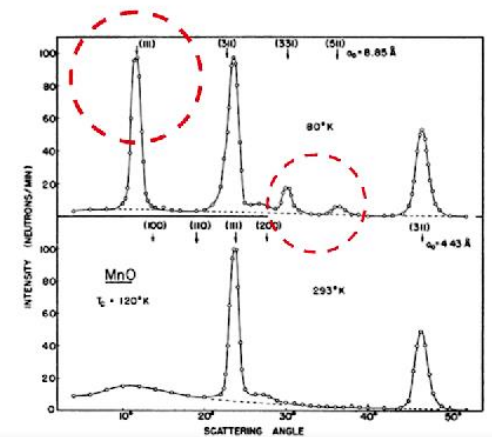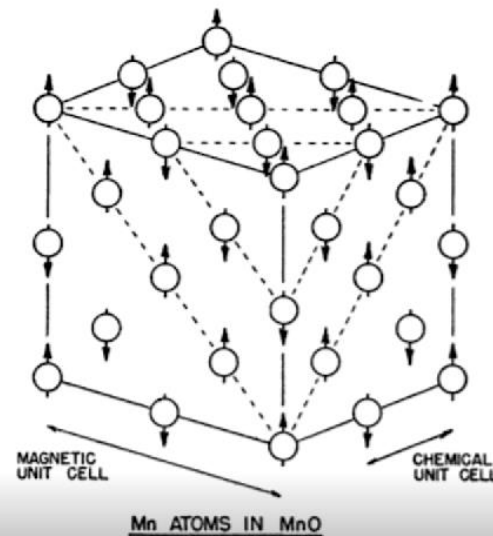Constructive interference:
Bragg peaks
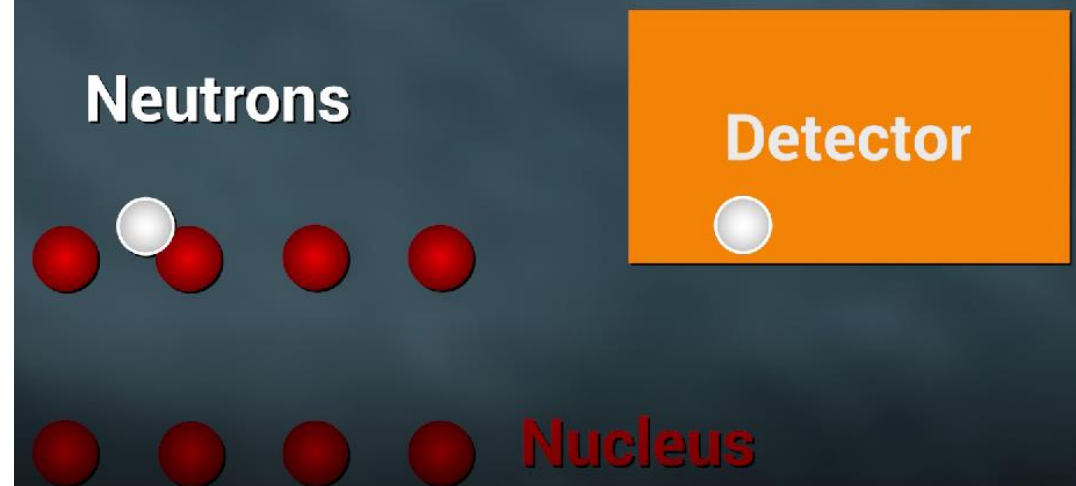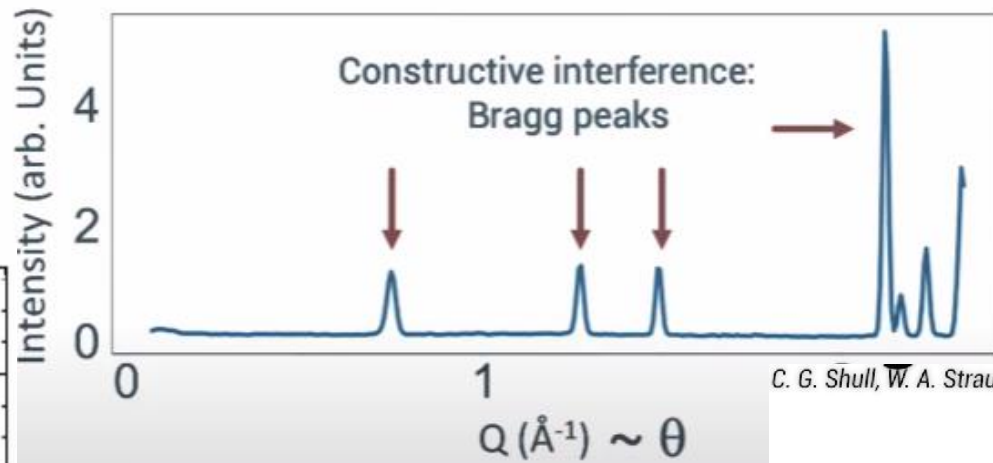
C. G. Shull, W. A. Strauser, and E. O. Wollan Phys. Rev. 83, 333 (1951)

Module 2

Module 1

Module 3

II) RESEARCH APPLICATIONS VIDEOS

- 5-10 min videos for upper year undergraduate and other graduate students

- Recorded by current MSc and PhD students

- Current research and applications of neutron scattering

  - quantum magnetism

  - geometric frustration

  - membrane biophysics

  - drug delivery

  - neutrons for health

Application of Neutron Scattering:

The interplay of **spin liquid** and **spin glass** ground states in novel antiferromagnet $YbCoGaO_4$

Symphony Huang
McMaster University
Supervisor: Dr. Bruce Gaulin

III) VIRTUAL LAB EXPERIMENTS

- Upper-year undergraduate students

1. Introduction to neutron diffraction
2. Assessing crystal quality and pole figures
3. Structural phase transitions
4. Magnetic scattering
5. Inelastic scattering and neutron spectroscopy
6. Neutron attenuation and interactions with matter

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III) VIRTUAL LAB EXPERIMENTS

- Lab instruction
  - Background and theory
  - Summary of the experiment
  - Questions
- Video
  - Instrument
  - Data collection
- Data

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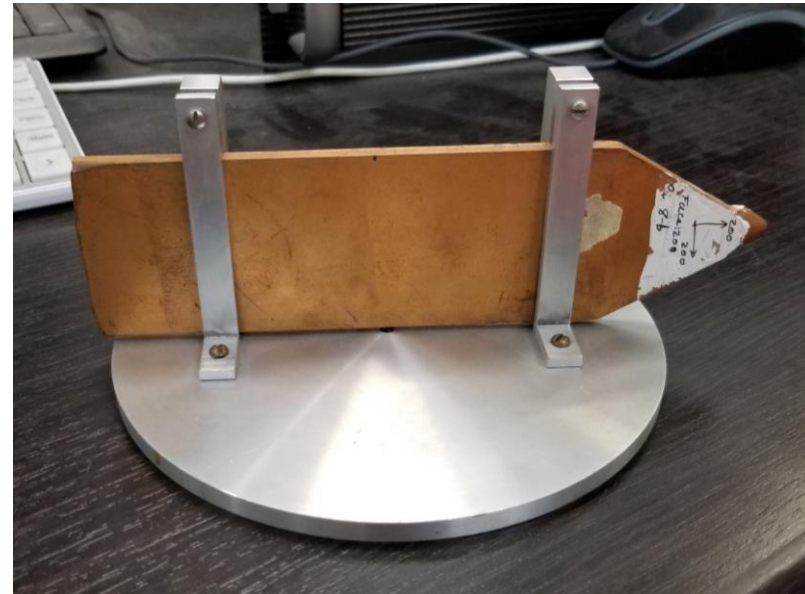
III) VIRTUAL LAB EXPERIMENTS

- One-semester practical introduction to neutron scattering course

- Modules in an existing upper-year laboratory/experimental methods course

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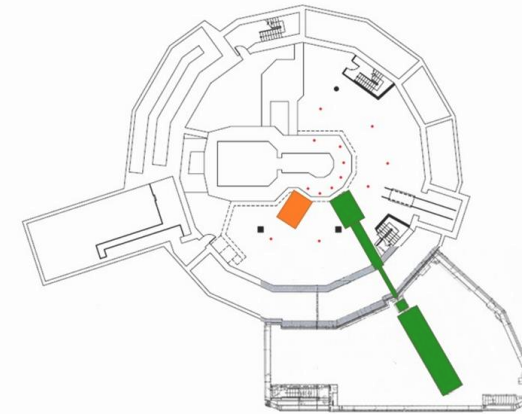Physics & Astronomy

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IV) MAD AND MacSANS SIMULATION

- By Taryn McMillan (Software Developer, Mystic Mill Games)

- To illustrate the operating principles of common neutron instrumentation:

  - Removable shielding

  - Interactive components

  - Adjustable experimental parameters

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IV) MAD
MCMASTER ALIGNMENT DIFFRACTOMETER

- A general-purpose triple-axis neutron spectrometer located on Beamport #6

BP#4: Small Angle Neutron Scattering (MacSANS)

BP#6: General Purpose Diffractometer (MAD)

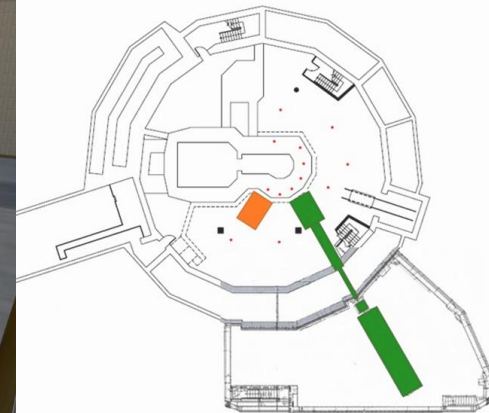**SCIENCE** Department of Physics & Astronomy

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IV) MacSANS
MCMASTER SMALL-ANGLE NEUTRON SCATTERING FACILITY

- A new SANS instrument currently under construction on Beamport #4. MacSANS is scheduled to begin commissioning experiments in **Fall 2022**.

BP#4: Small Angle Neutron Scattering (MacSANS)

BP#6: General Purpose Diffractometer (MAD)

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IV) MAD
MCMASTER ALIGNMENT DIFFRACTOMETER

IV) MacSANS
MCMASTER SMALL-ANGLE NEUTRON SCATTERING FACILITY

IV) MacSANS
MCMASTER SMALL-ANGLE NEUTRON SCATTERING FACILITY

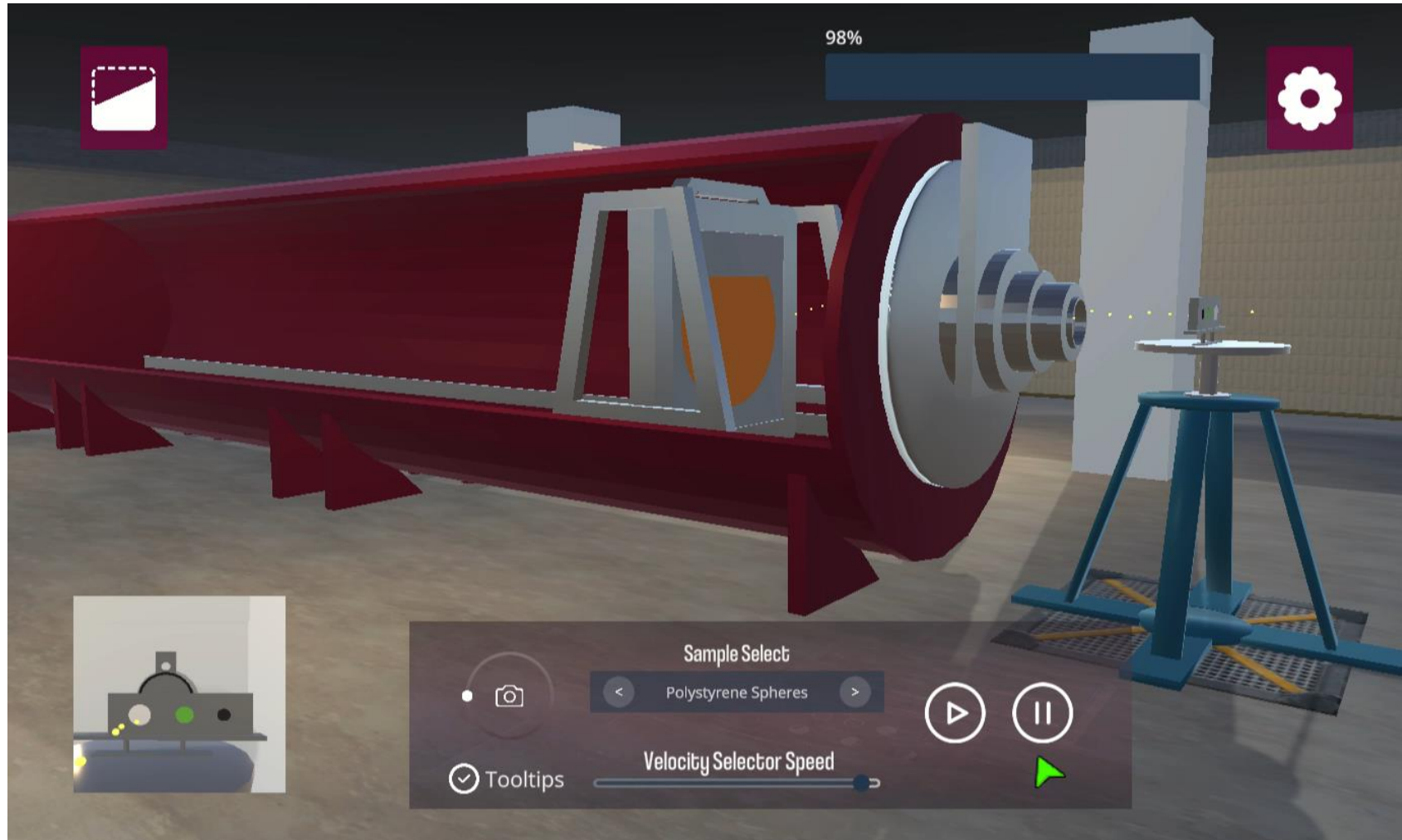# IV) MacSANS
MCMASTER SMALL-ANGLE NEUTRON SCATTERING FACILITY

PEOPLE

- Dr. Pat Clancy (Principal Investigator, McMaster University)

- Evan Smith (PhD student, McMaster University)
- Symphony (Hsiao-Yuan) Huang (PhD student, McMaster University)
- Yijia Zi (MSc student, McMaster University)

- Greg Van Gastel (Educational Developer, MacPherson Institute, McMaster University)

- Taryn McMillan (Simulation Developer, Mystic Mill Games)

ACKNOWLEDGMENT

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THANKS

- Content will be hosted in central collection: vlslibrary.ecampusontario.ca (by Jan 2023)

- All resources will be freely available under creative commons license (CC BY-NC-SA)

- **bit.ly/MacNeutronSim**
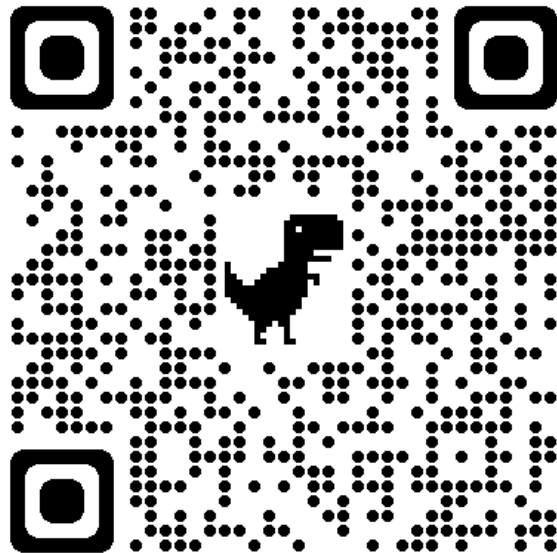
Questions, comments and feedbacks:
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