A New Canadian Neutron Beam Science Program at the McMaster Nuclear Reactor

McMaster Nuclear Reactor 2021

McMaster Nuclear Reactor circa 1958

5 MW nuclear reactor - typically operates at 3 MW

Bruce D. Gaulin
McMaster University

CIFAR

CINS CANADIAN INSTITUTE FOR NEUTRON SCATTERING

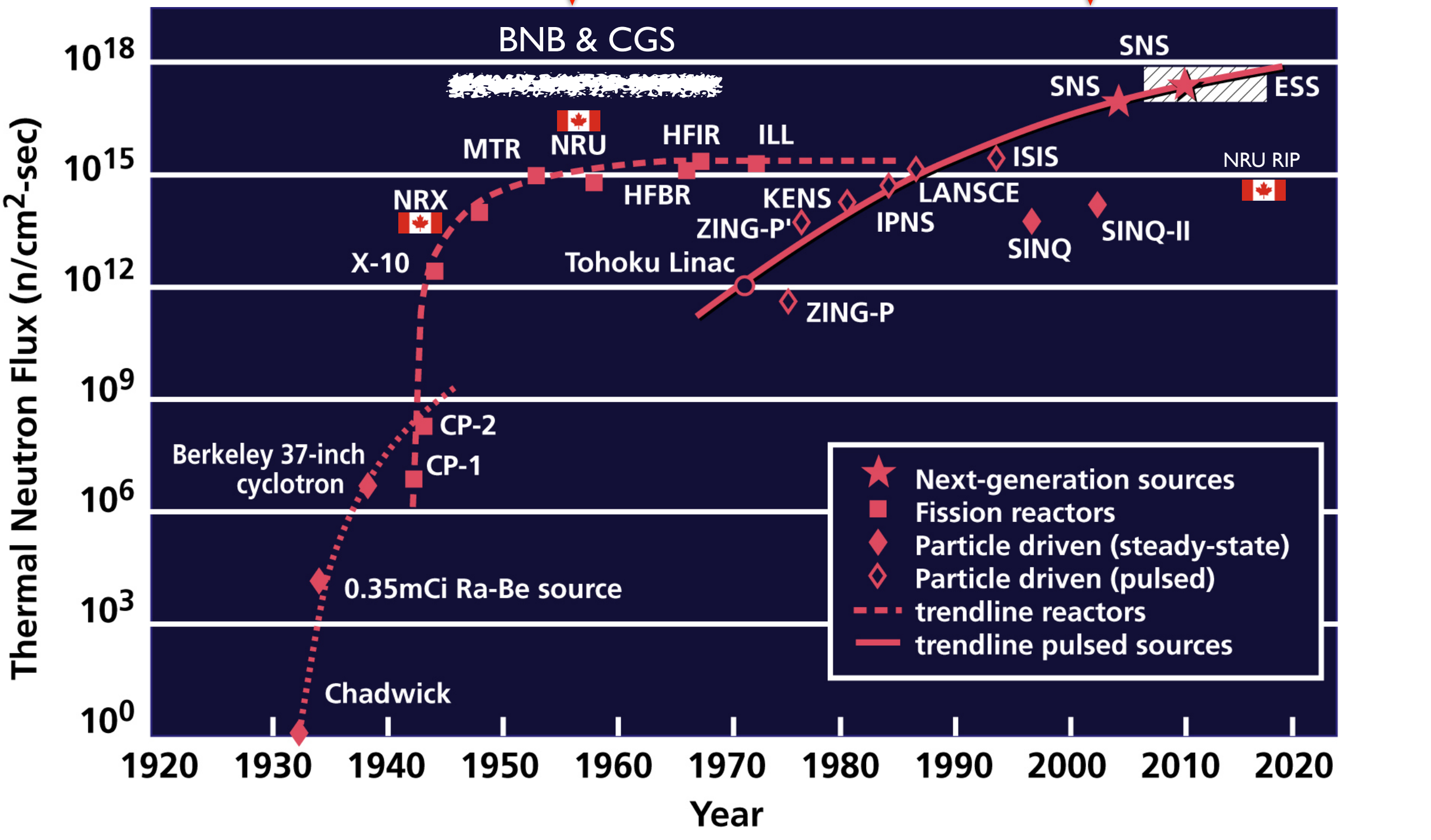
Canada has played a heroic role in the development of neutron beam science

Bert Brockhouse with grad alumni at his McMaster retirement celebration (~1985)

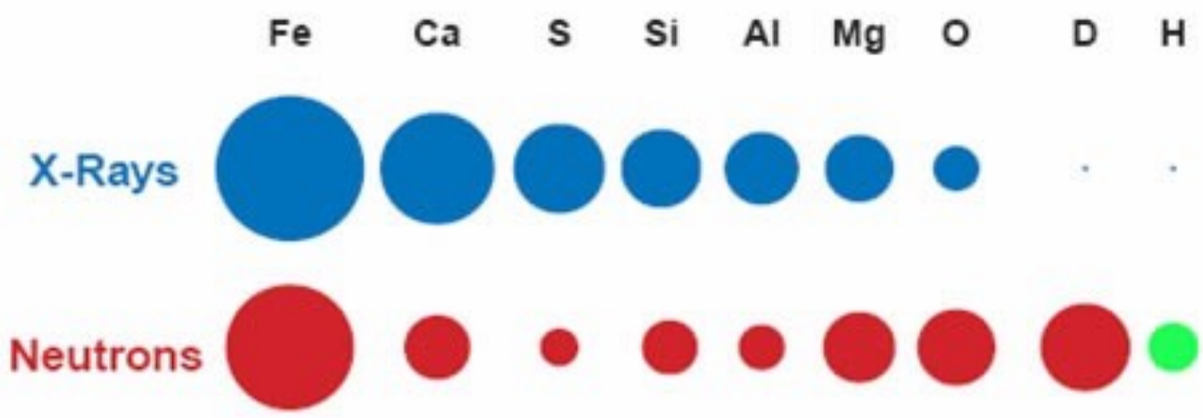
Development of Neutron Science Facilities

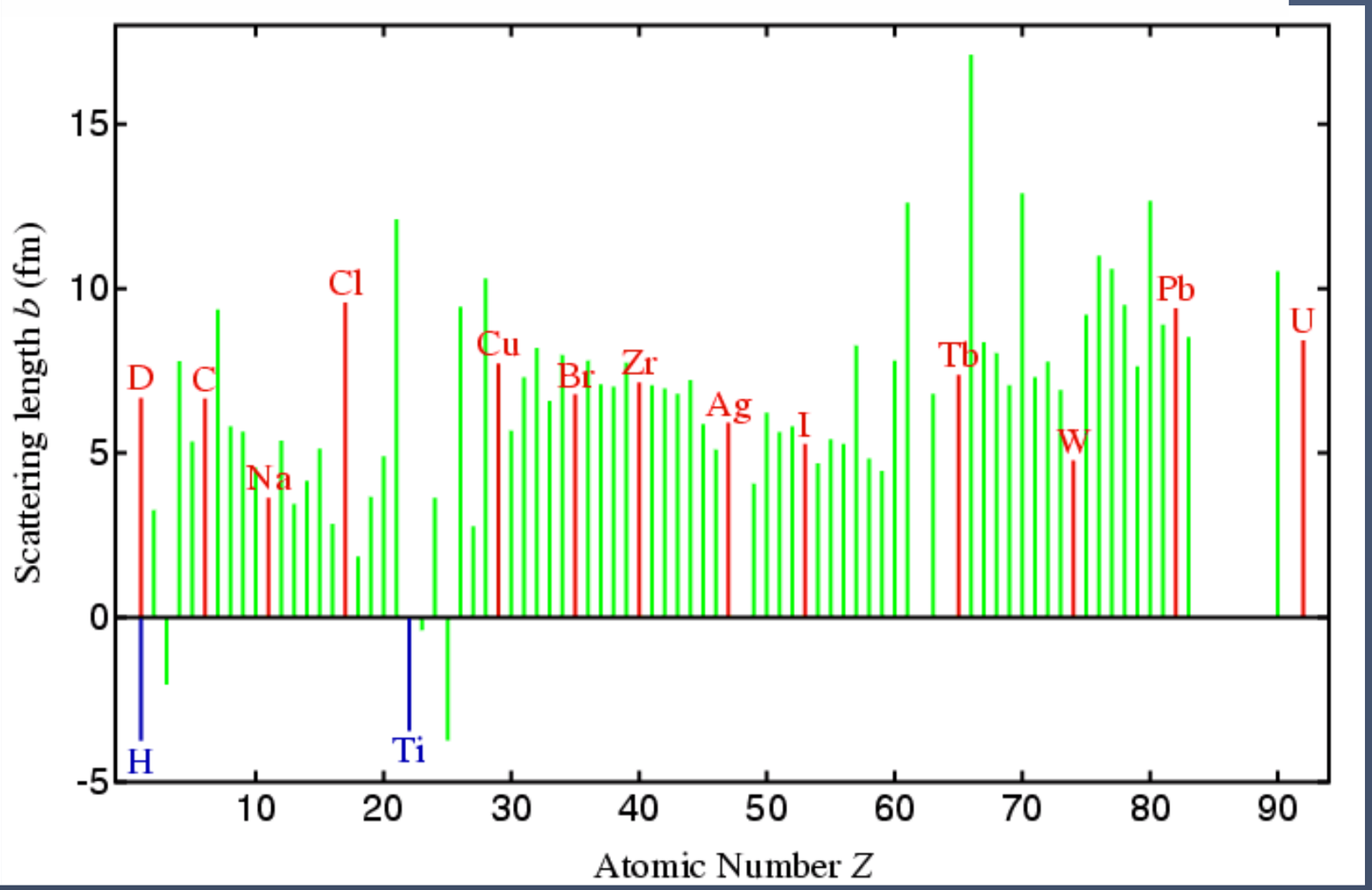
Initial investment

~ $8 B reinvestment



Neutrons scatter off *nuclei*





Neutrons "see" nuclei and magnetism

X-rays - electromagnetic radiation "see" electrons

“Killer Applications” for Neutron Scattering

- **Magnetism**
- **Hydrogenous materials**
- **Light Elements, especially oxides**
- **4D $\vec{Q}, \hbar\omega$ studies**
- **Studies at depth**

2021 CFI IF $14.2M ($47M total) award
“Building a Future for Canadian Neutron Scattering”

Vision :

- **Optimally exploit MNR**
  for neutron *diffraction* programs
  over a broad range of materials science
  and engineering problems

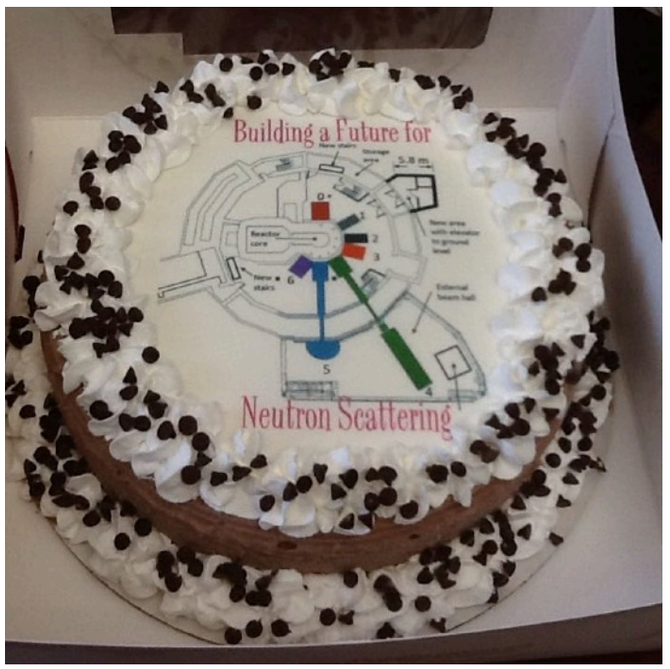
- **Initiate partnerships with world-leading**
  neutron beam centres
  for immediate access to neutron *spectroscopy*
  and other specialized applications

CFI IF "Building a Future for Canadian Neutron Scattering"

Table 1: Team members' research themes. Asterisks (*) denote the 10 primary team members.

Quantum Materials (Q)	Energy Materials (E)	Structural Materials (S)	Biomaterials (B)	Instrument Development
Gaulin*, McMaster	Frisken*, SFU	Daymond*, Queen's U.	Marquardt*, U. Windsor	Daymond*
Hallas*, UBC	Huot*, UQTR	Chapman*, U. Saskatchewan	Cranston, UBC	Gaulin*
Kim*, U. Toronto	Tutolo*, U. Calgary	MacKay, Nemak	Hoare, McMaster	Kim*
Wiebe*, U. Winnipeg	Goward, McMaster	Noel, Western	Dutcher, U. Guelph	Noel
Aronson, UBC	Nazar, U. Waterloo	Rogge, CNL	Harroun, Brock	Rheinstadter
Bianchi, U de M	Ryan, McGill	Sediako, UBC	Leonenko, U. Waterloo	Rogge
LeBlanc, MUN	Mozharivskyj, McMaster		Rheinstadter, McMaster	Yamani
Monchesky, Dalhousie			Unsworth, U. Alberta	
Yamani, CNL				

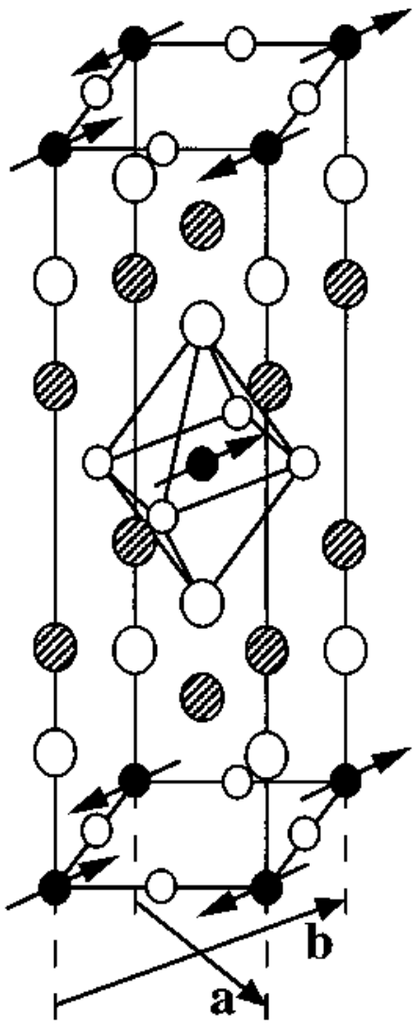
19 Canadian universities from coast to coast participated



Success!

Structure determines function

Cu^{2+}: S = 1/2



High temperature superconductivity

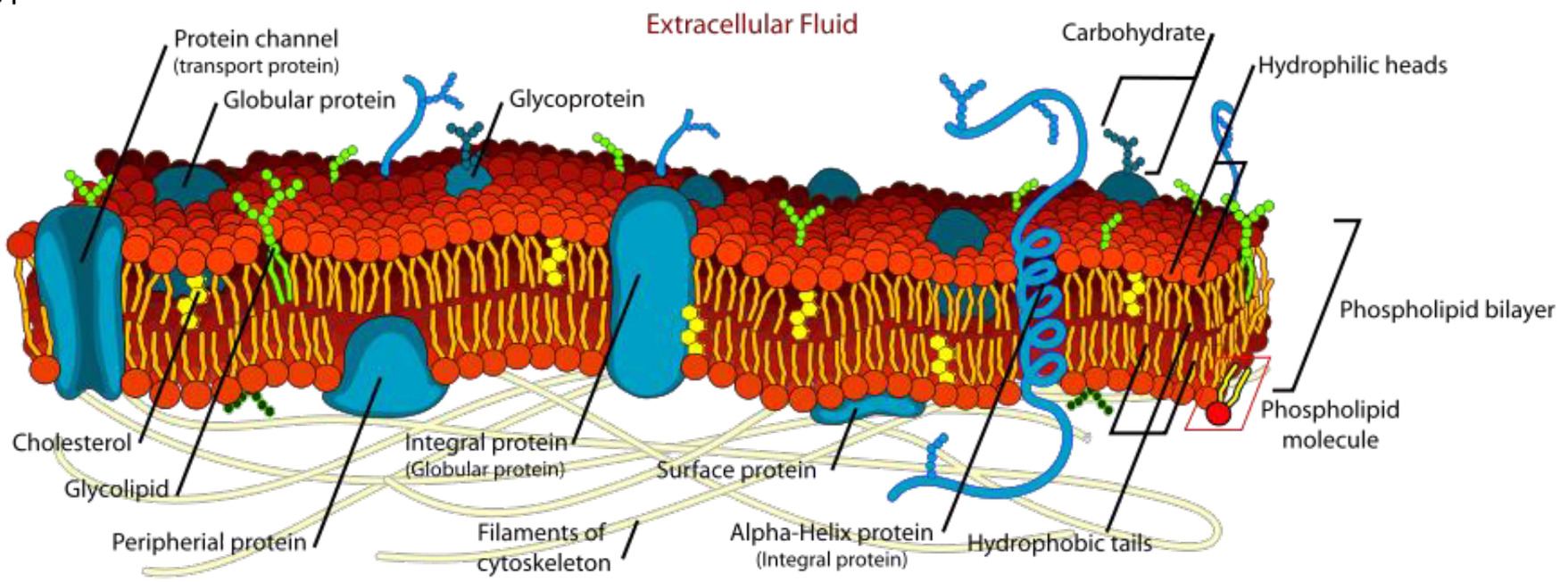
La_2CuO_4

- ● Cu^{2+}
- ○ O^{2-}
- ○ O^{2-}
- ◍ La^{3+}

Many "Grand Challenge" Problems Related To:

- **Energy**
- **Environment**
- **Information Technology**
- **Health**

are materials problems



A biological membrane

Structure determines function

Many "Grand Challenge" Problems Related To:

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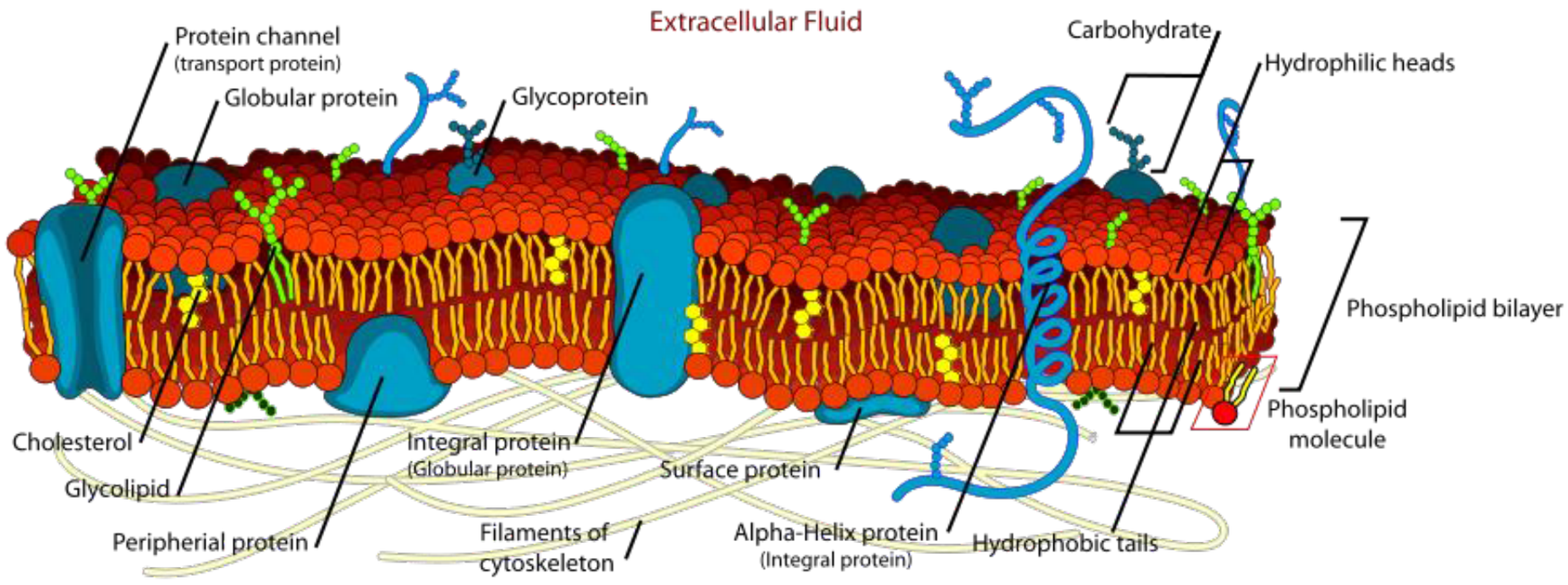
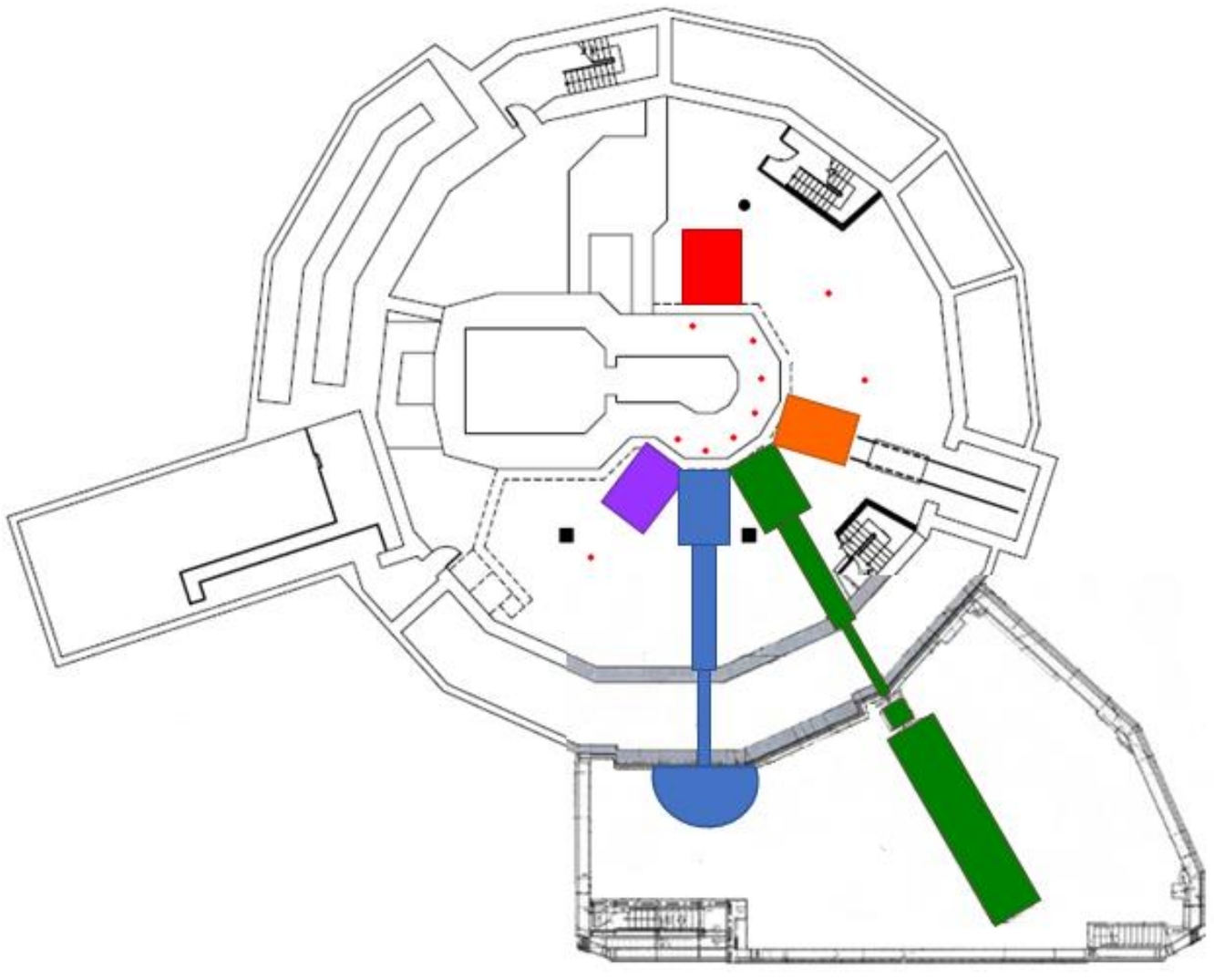
High temperature superconductivity



A biological membrane

CFI IF “Building a Future for Canadian Neutron Scattering”

~ $20 M in new neutron instrumentation for MNR



BP#0: Neutron Reflectometer

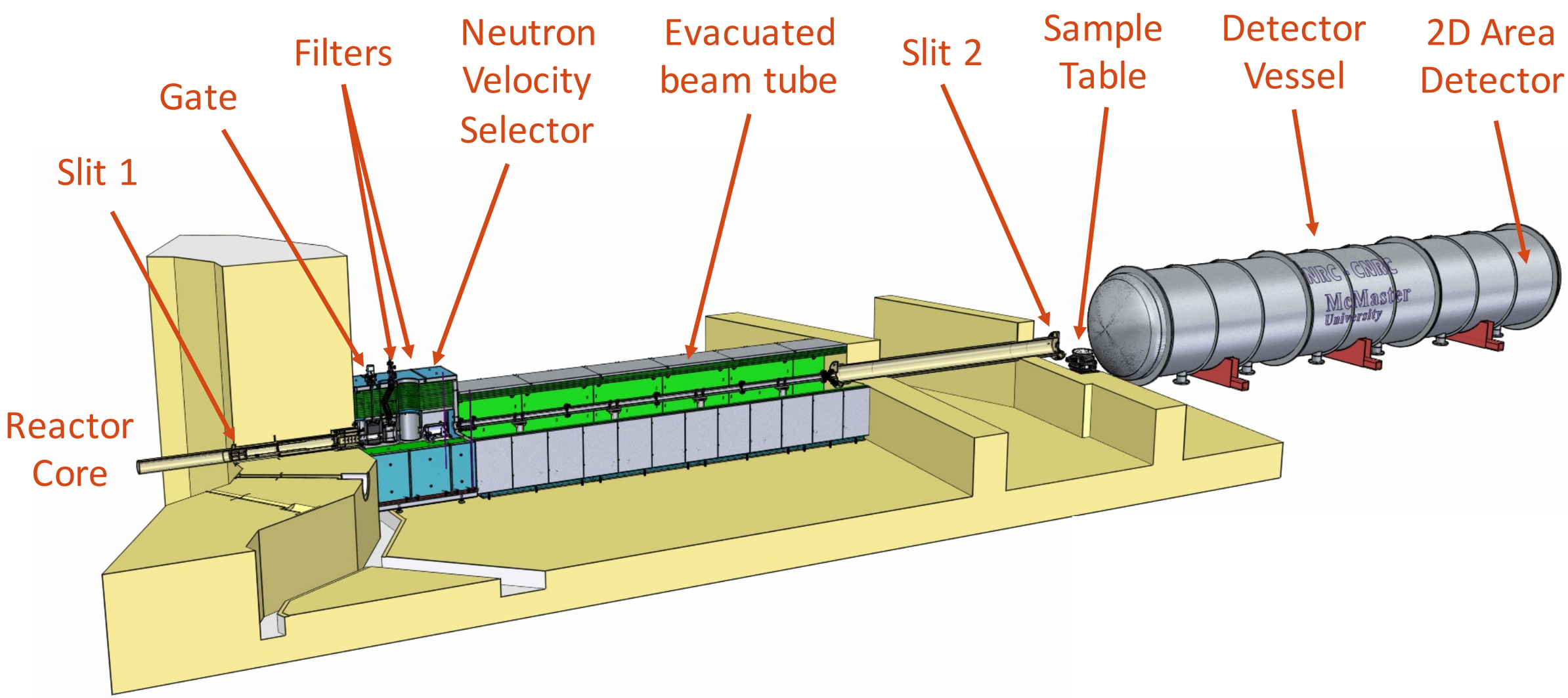
BP#3: General Purpose Diffractometer (MAD), shared with Prompt Gamma Facility

BP#4: Small Angle Neutron Scattering (MacSANS)

BP#5: Neutron Powder Diffractometer, shared with Intense Positron Beam Facility

BP#6: Neutron Stress Scanner Industrial Diffractometer

New $7M **McSANS** instrument at MNR Beam Port 4
Completion set for November 2021



Beam Port insert set for installation
June 2021 shutdown

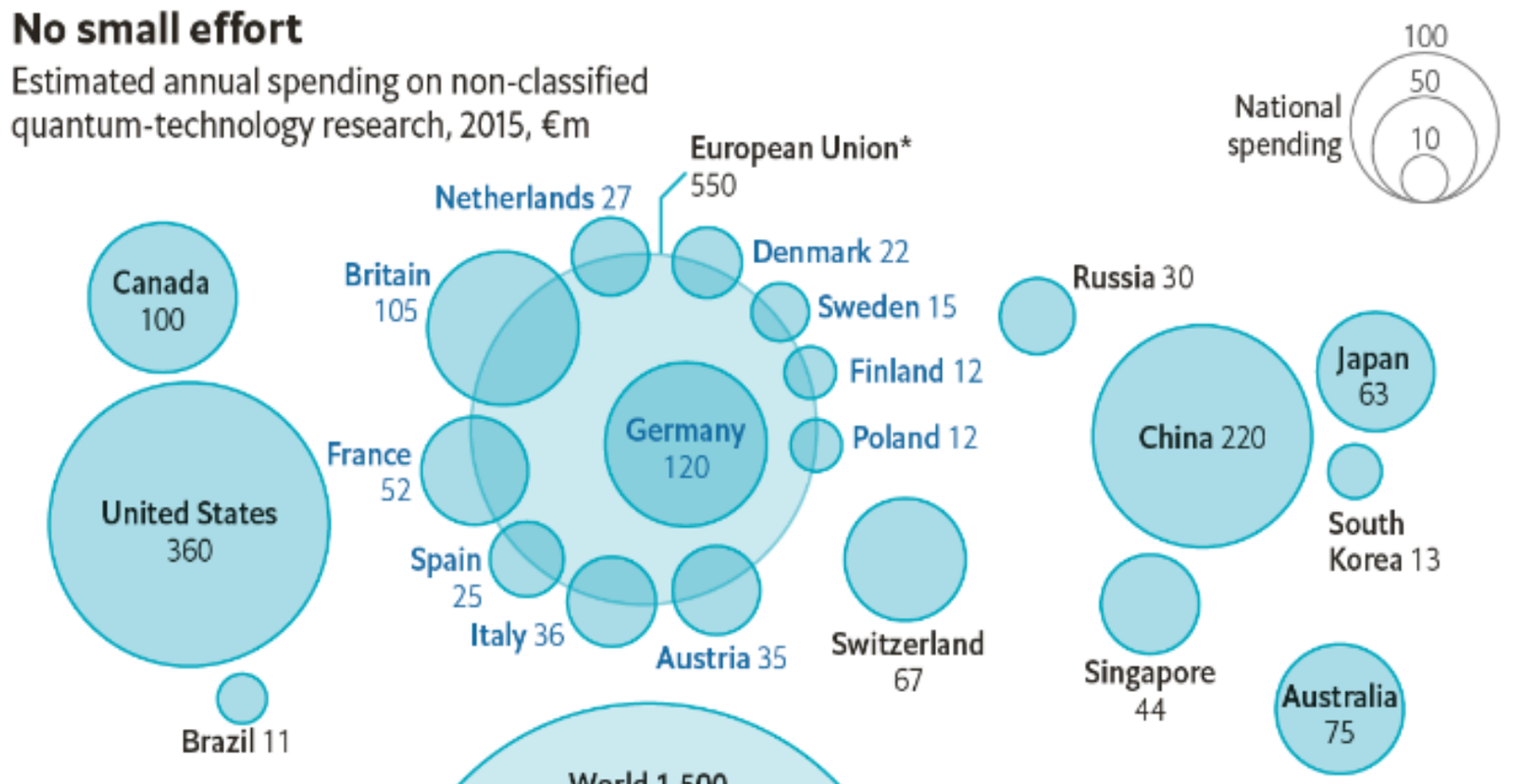
2D detector expected
Fall 2021

Canada's National Quantum Strategy

Line item in 2021 Federal Budget: $360M over 7 years

CIFAR supports international research programs based on Canadian excellence in:

- ***Quantum Materials***
- ***Quantum Information***



Neutron Scattering from New Quantum Materials

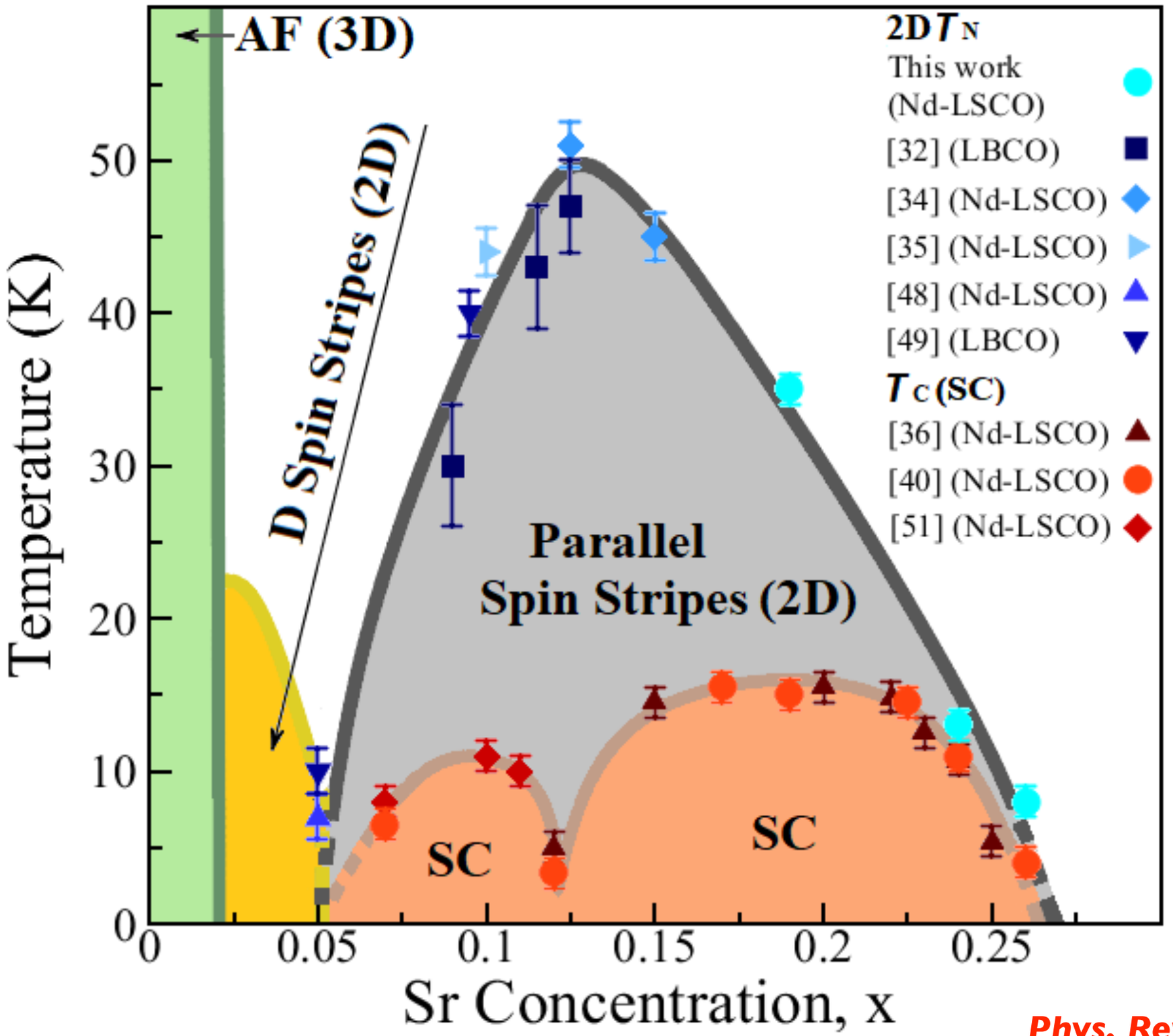
Neutron Scattering :

- Powerful probe of magnetism
- Sensitive to light elements; eg oxygen
- Elucidates structure and dynamics

Quantum Materials :

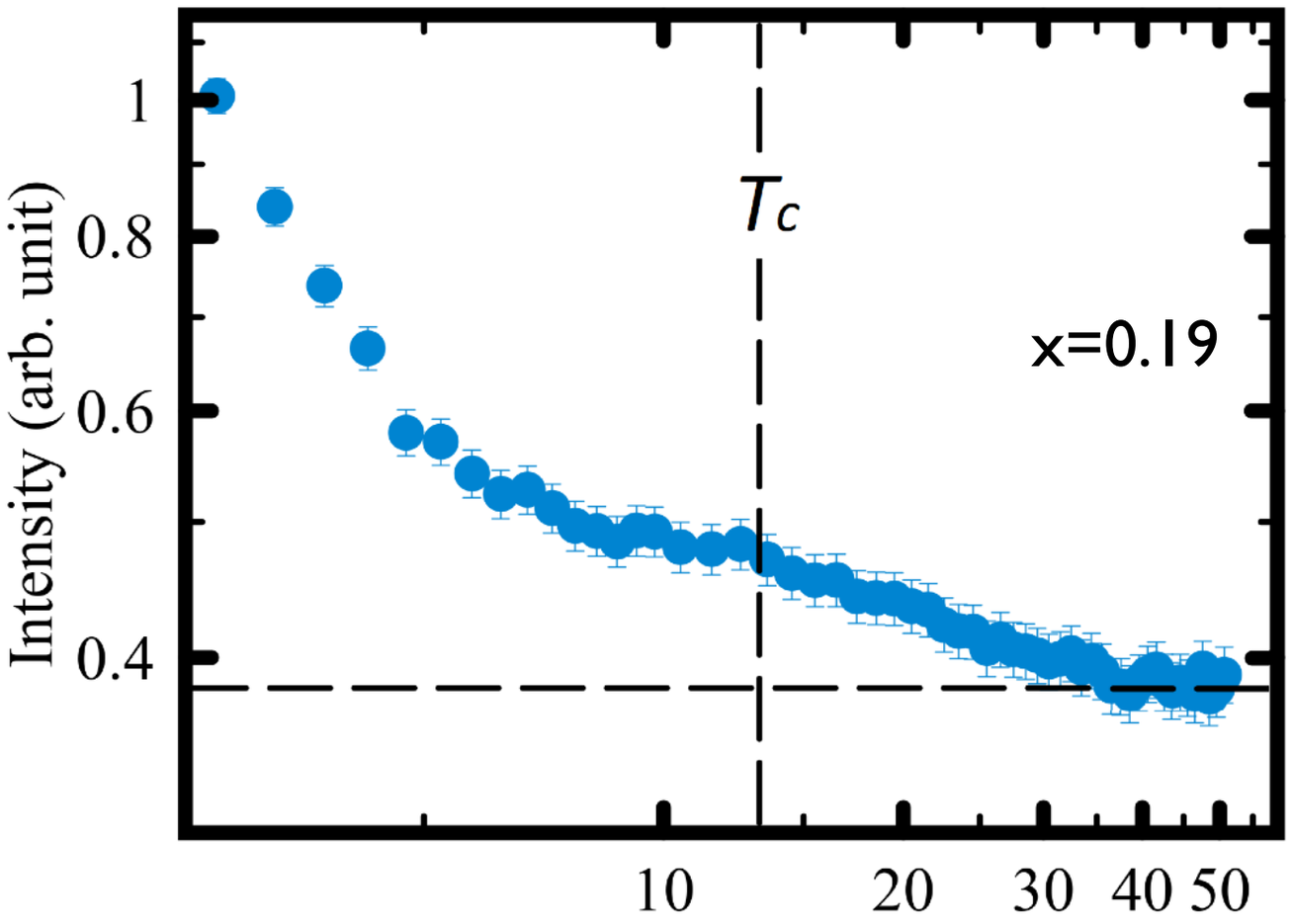
- Magnetism often intertwined with quantum states or is the quantum state of interest itself
- Often transition metal oxides; combine heavy and light elements
- Structure and dynamics determine properties

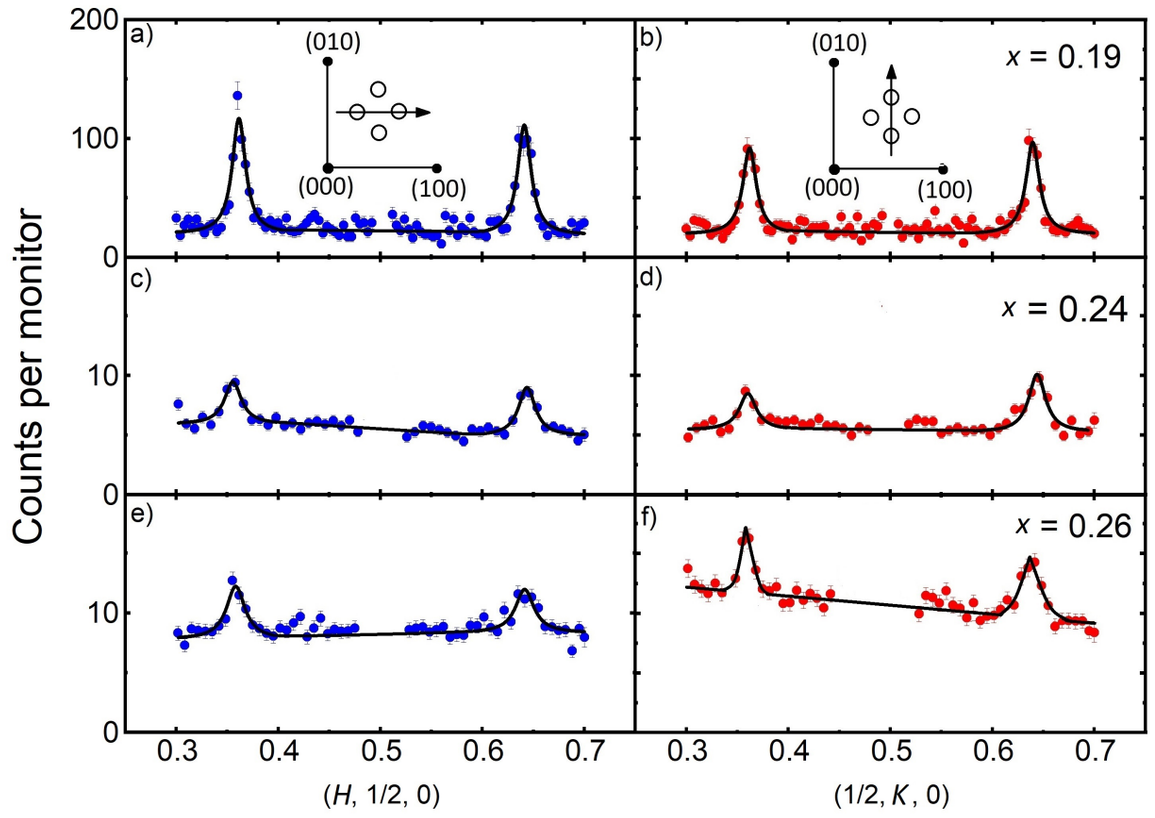
Our magnetic phase diagram for $La_{(1.6-x)}Nd_{0.4}Sr_xCuO_4$ (Nd-LSCO)

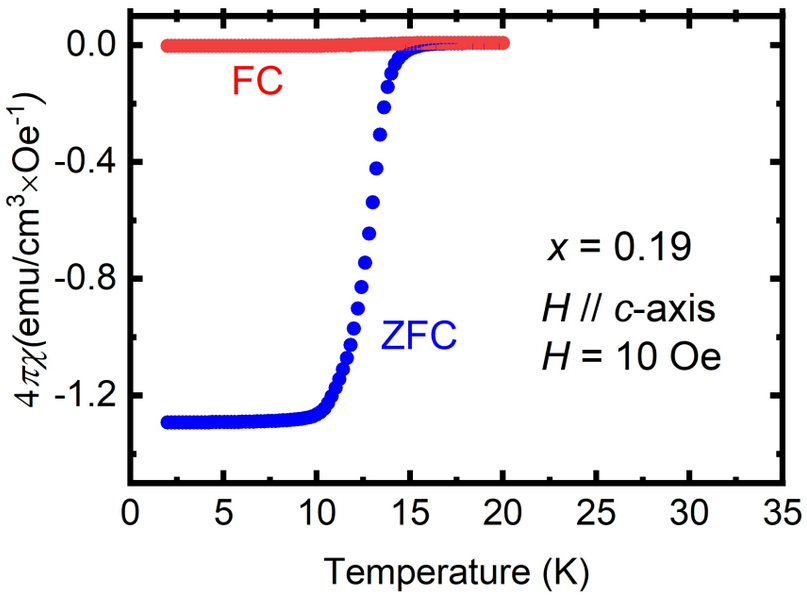


Q. Ma et al,
Phys. Rev. Research, 3, 023151(2021)

Triple axis measurements allow for parametric studies of phase behaviour

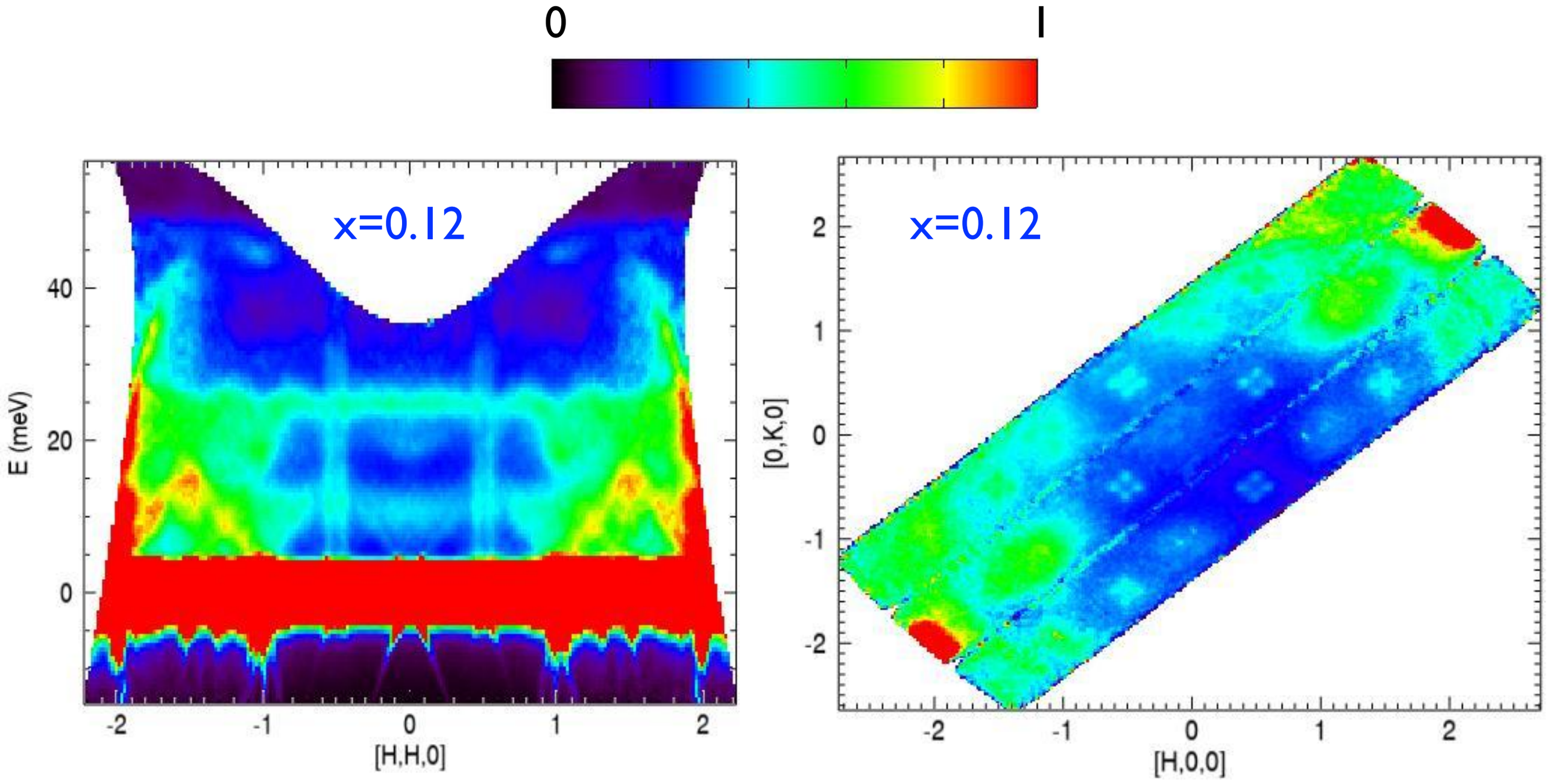






Q. Ma et al,
Phys. Rev. Research, 3, 023151(2021)

Time-of-flight measurements give broad survey of structure and dynamics in Nd-LSCO

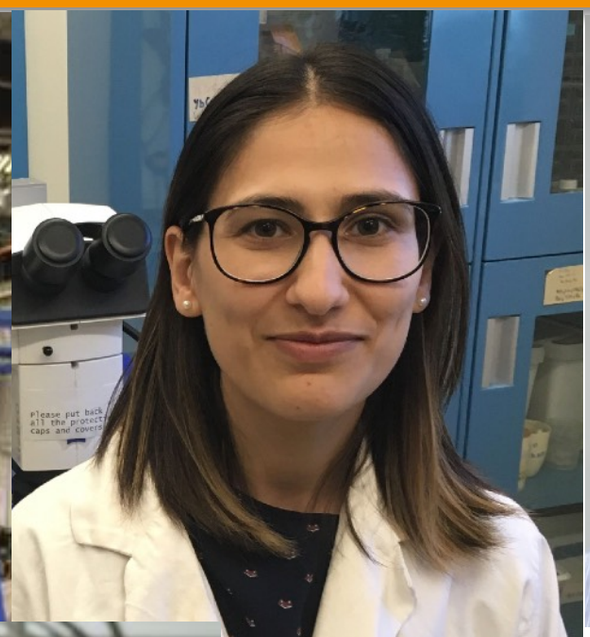


TOF as a function of $\hbar\omega$

$\Delta(\hbar\omega)$ ~1.2 meV; $\int -4 \le L \le 4$

$\int 5\,meV \le \hbar\omega \le 10\,meV \quad \int -4 \le L \le 4$

Collaboration:



M. Dragomir, Q. Ma et al., Phys. Rev. Materials, 4, 114801 (2020)
Q. Ma et al, Phys. Rev. Research, 3, 023151 (2021)