

# Update on Neutron Facilities

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BESAC Meeting

December 6, 2021

ORNL is managed by UT-Battelle LLC for the US Department of Energy

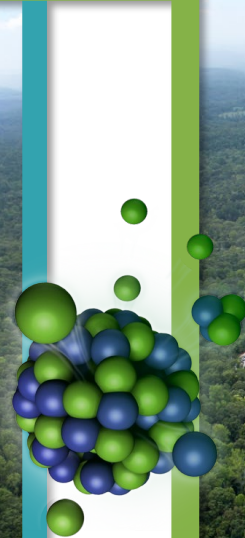
# ORNL Neutron Sciences operates two of the world's leading neutron facilities

High Flux Isotope Reactor (HFIR)

World's highest continuous neutron brightness



12 neutron scattering instruments



18 neutron scattering instruments

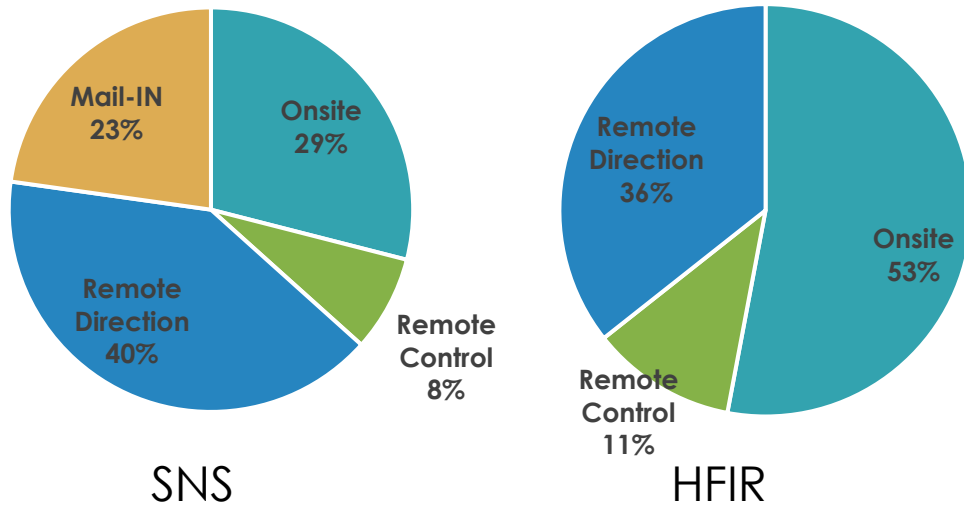
Spallation Neutron Source (SNS)

World's highest peak neutron brightness

# Users and publications

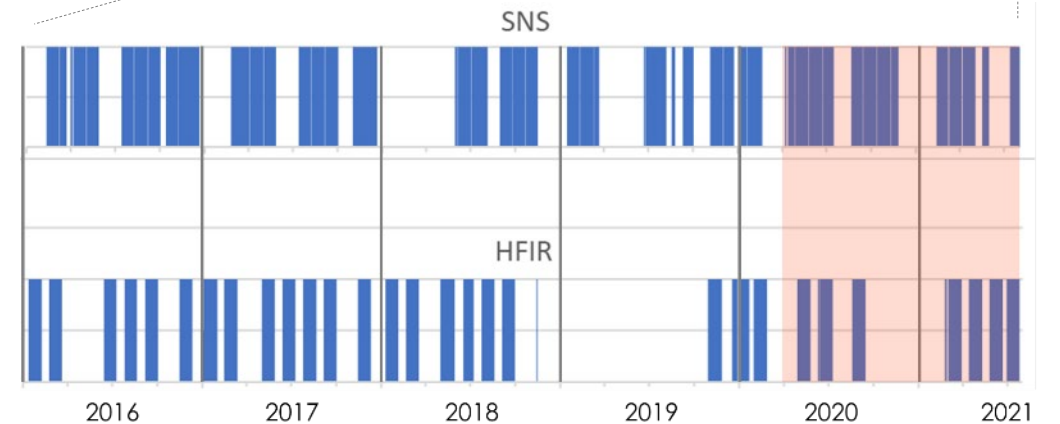
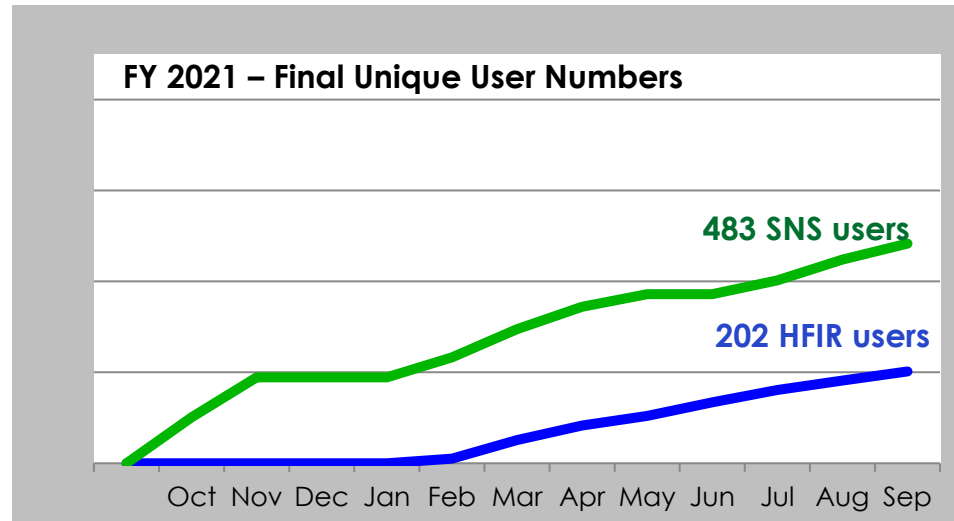
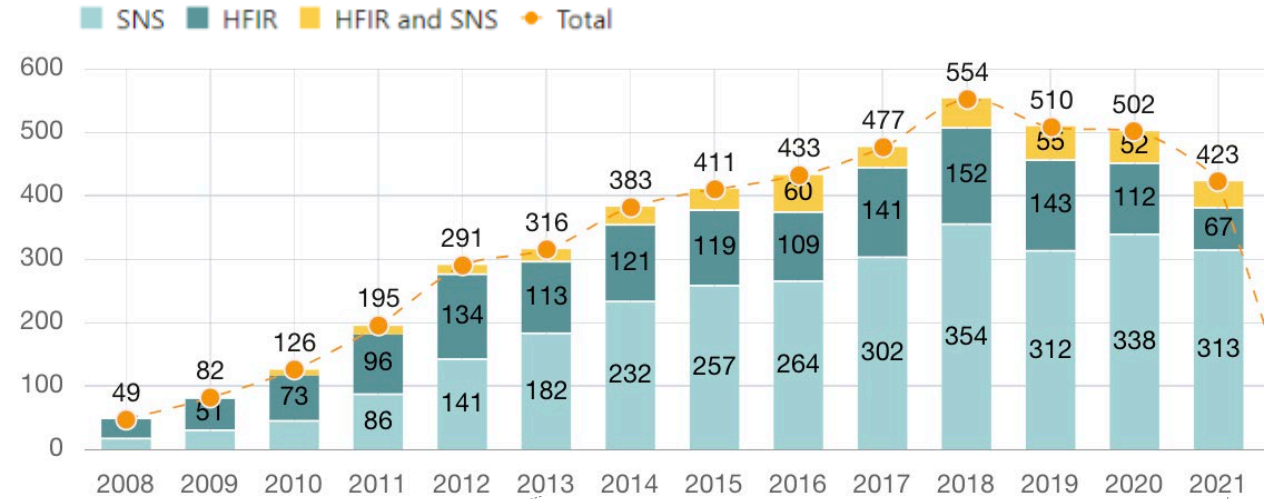
## Unique users by type

Oct. 1, 2020, through Sep. 30, 2021

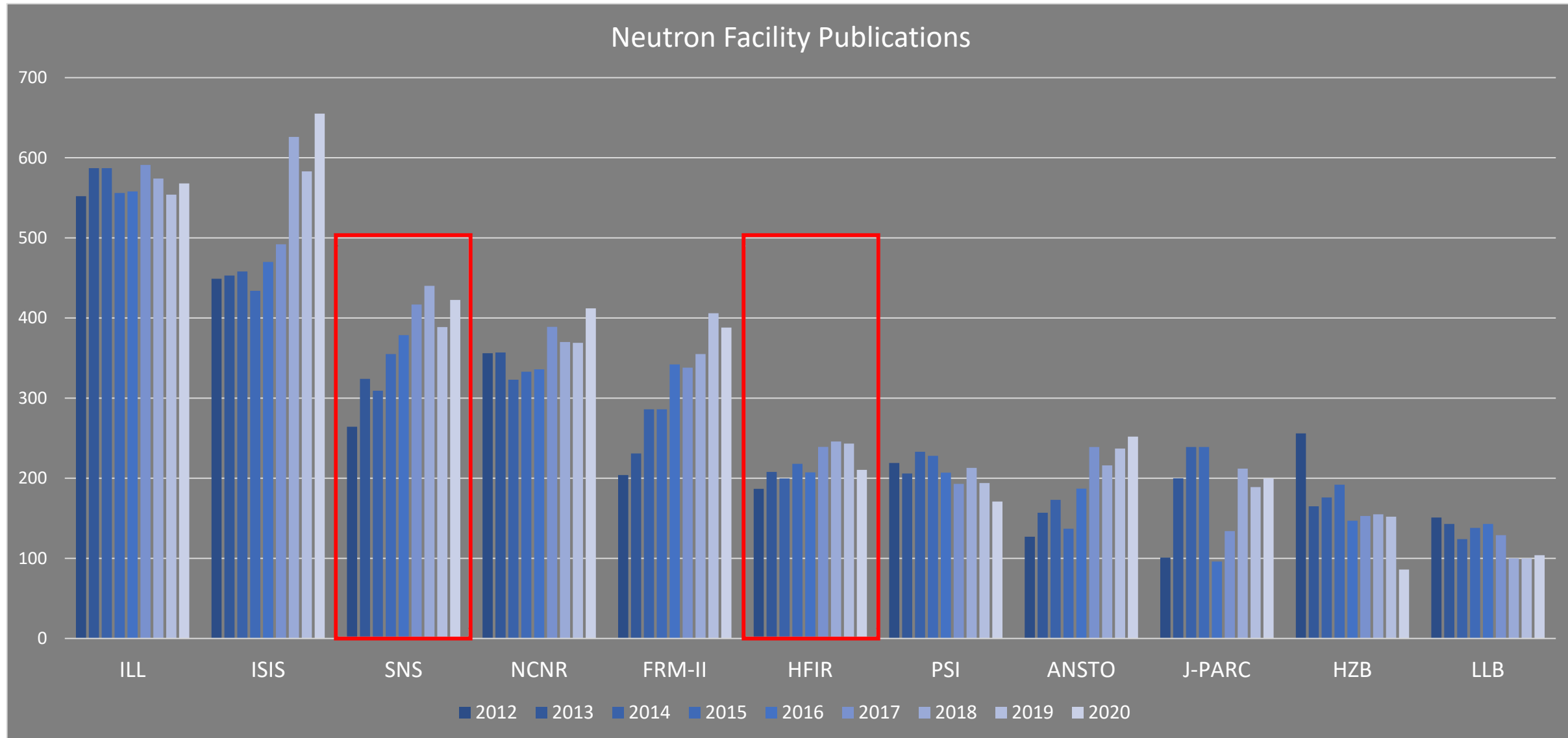


## Instrument publications

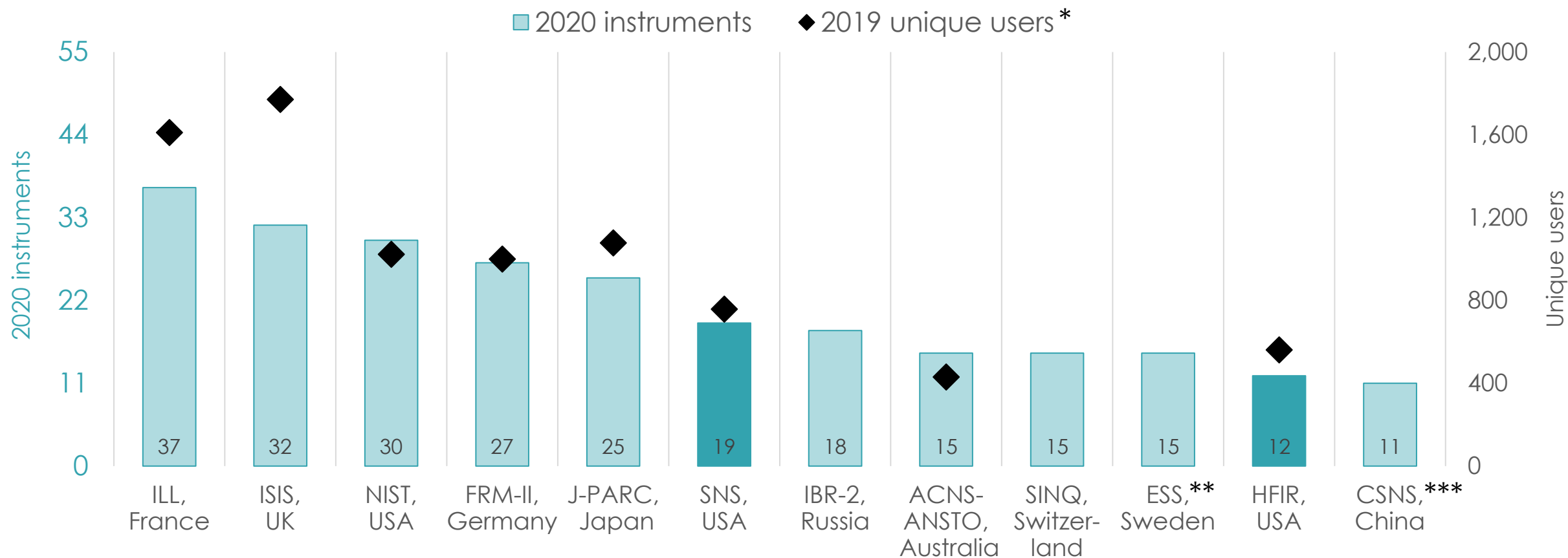
Instrument publications account for ~70-75% of all SNS/HFIR publications



# Neutron Facilities ranked by number of Publications



# Neutron Facilities ranked by number of Instruments

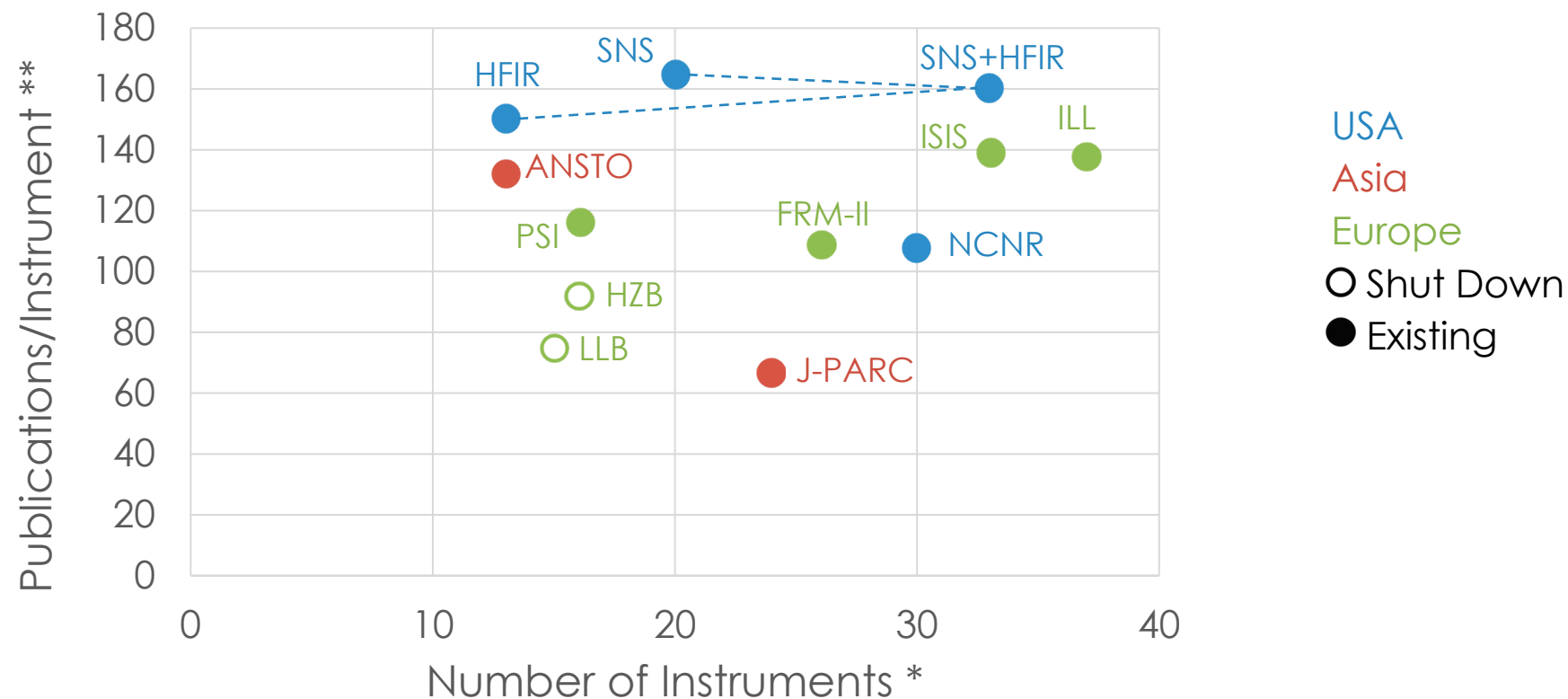


\* Pre-COVID. For HFIR, the user number is for 2018, since the facility was not running in 2019

\*\* ESS: Plan to ramp up instruments over 2025-28

\*\*\* CSNS: 4 operational instruments + 7 under construction

# Publication Comparison



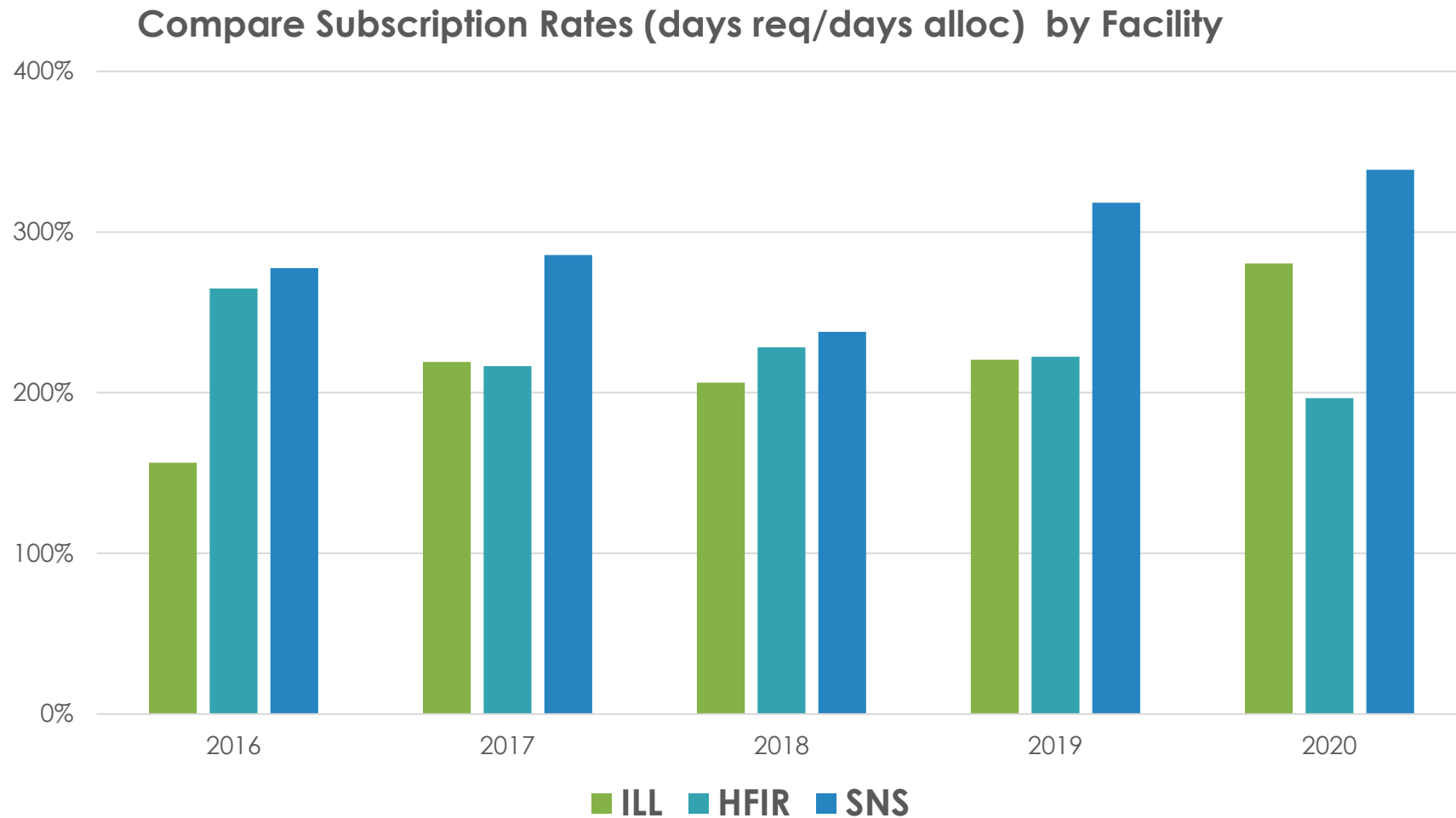
Horizontal Axis: Number of Instruments\* in 2020

Vertical Axis: Total number of publications\*\* 2012-2020 (inclusive) divided by number of instruments

\* Neutron beam instruments from most recent annual report, including muon and particle/fundamental physics experiments, but not including test and development beamlines

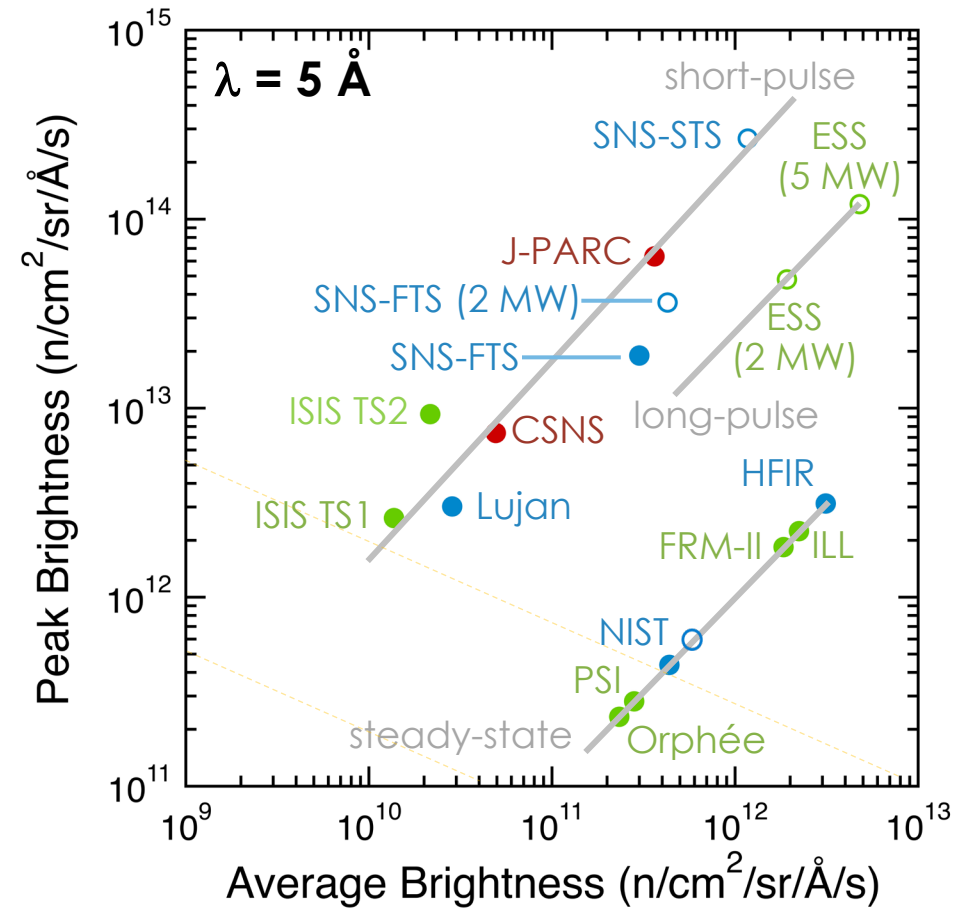
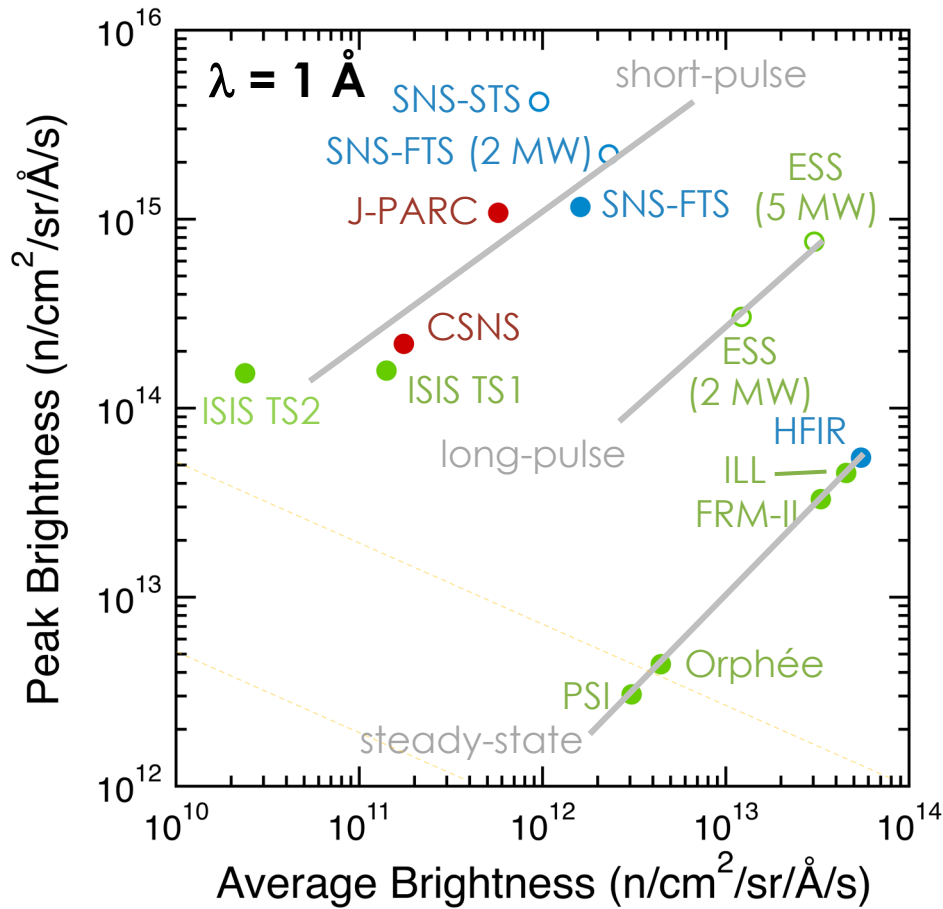
\*\* All publications from 2012 to 2020 (inclusive) taken from annual reports where available, including non-instrument publications, but not including theses/dissertations

# Subscription Rates compared to ILL



# SNS and HFIR provide world-leading source brightness

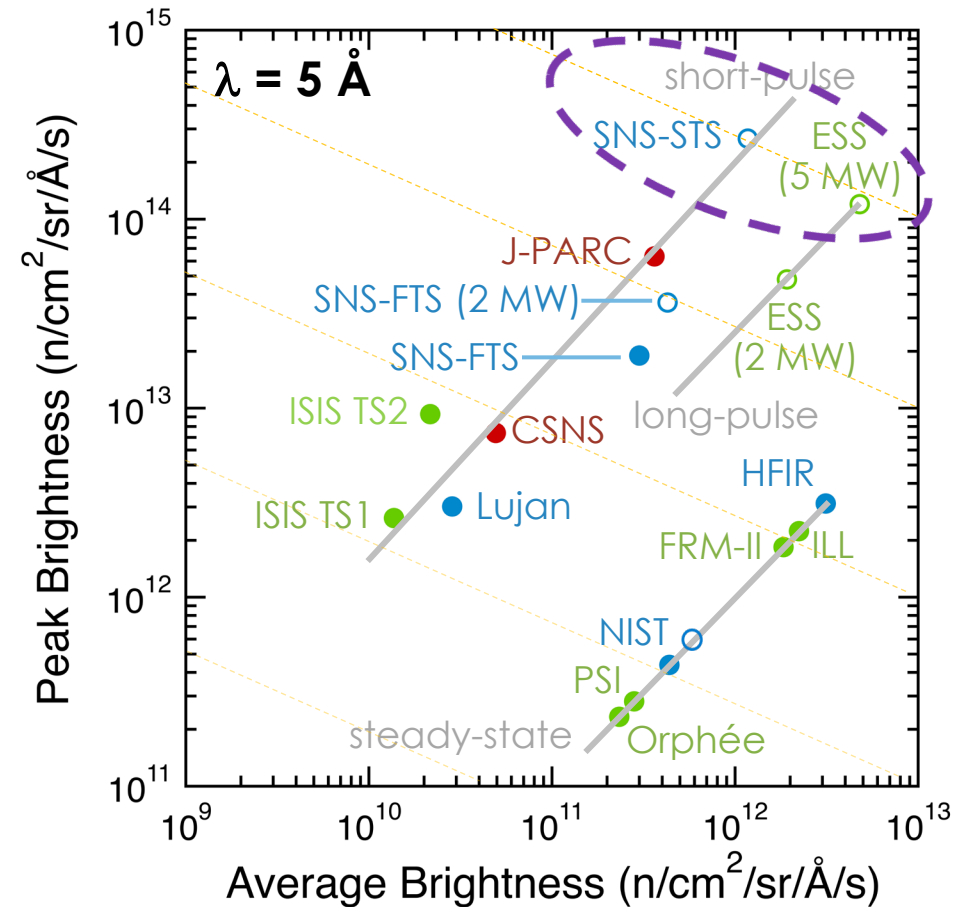
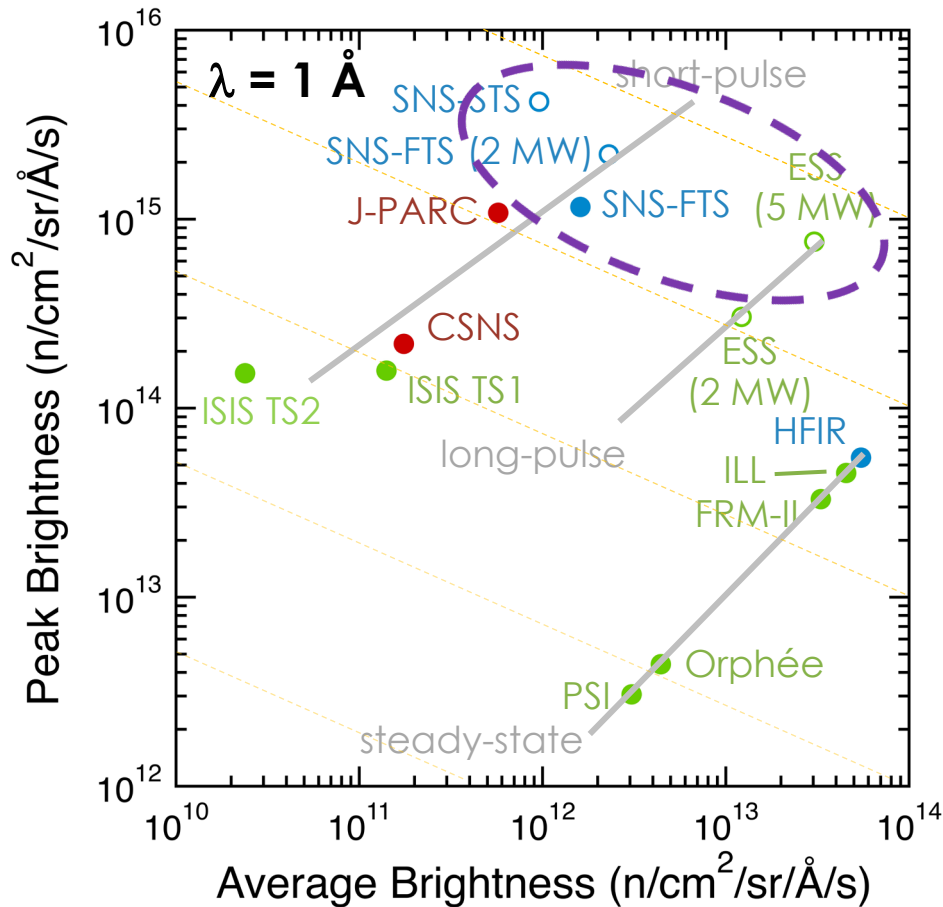
- USA
- Asia
- Europe
- Existing
- Planned





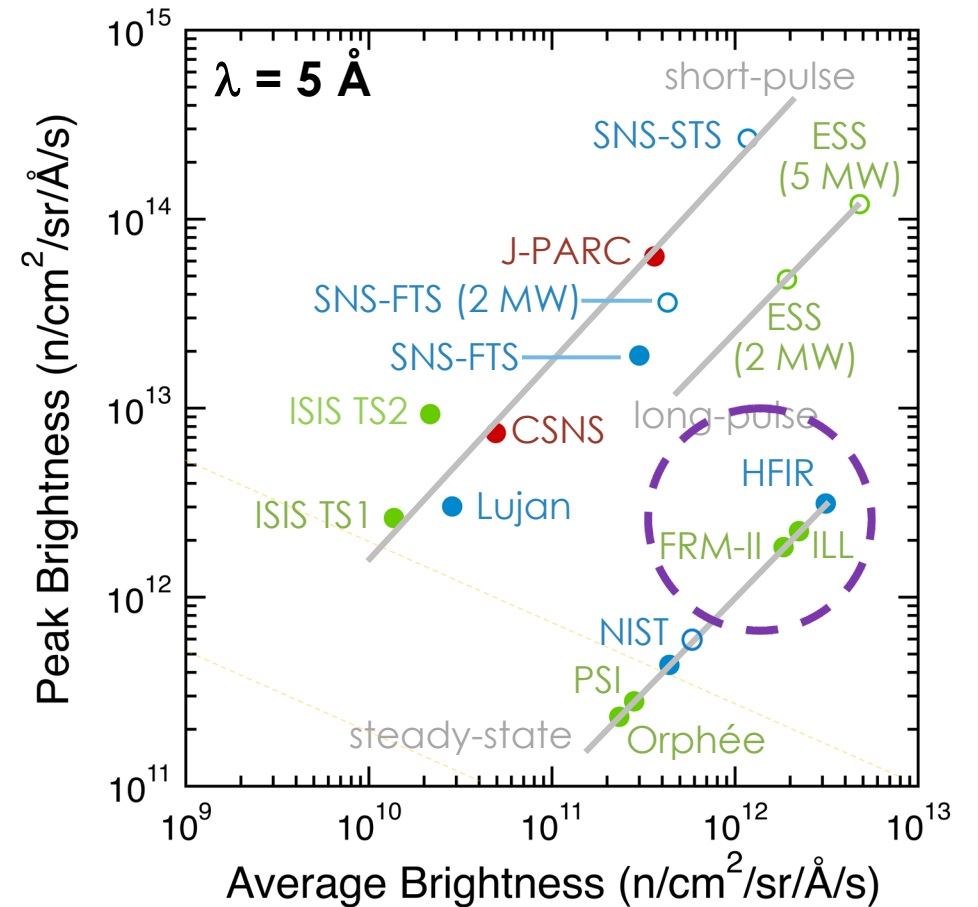
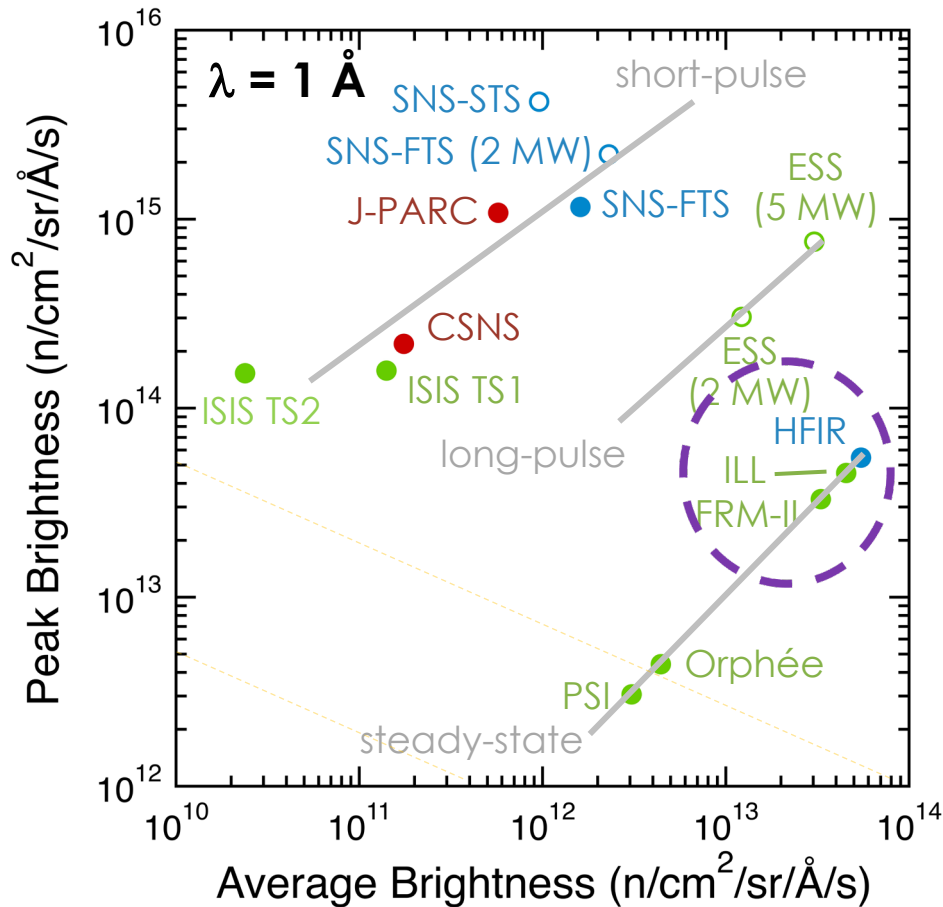
# SNS and HFIR provide world-leading source brightness

- USA
- Asia
- Europe
- Existing
- Planned



# SNS and HFIR provide world-leading source brightness

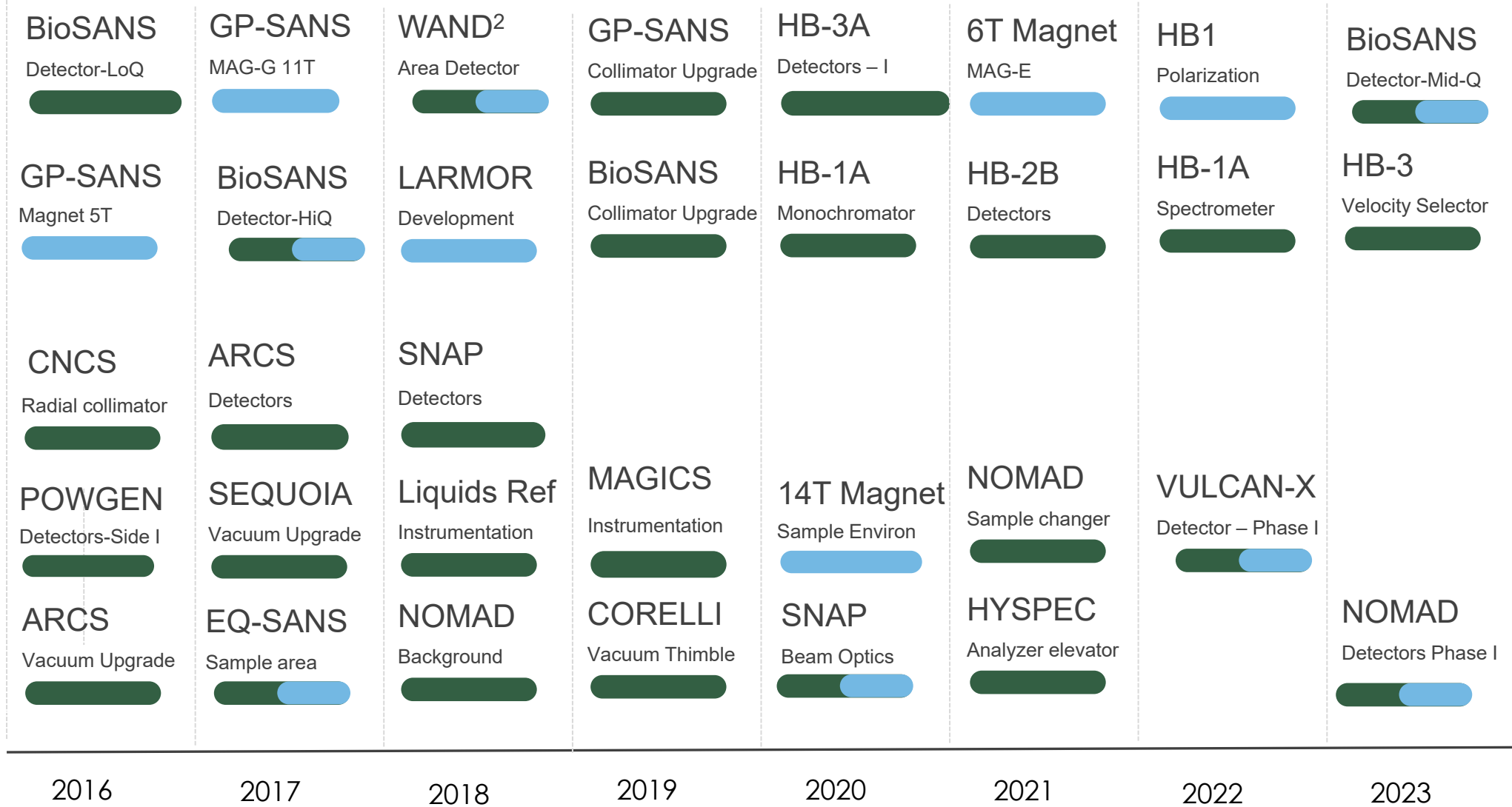
- USA
- Asia
- Europe
- Existing
- Planned



# Instrument Suite leverages high Source Brightness

12 HFIR instruments

18 SNS instruments



## PRIORITIZED

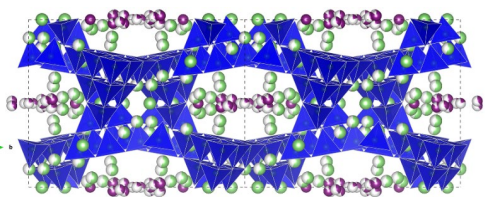
- GP-SANS Polarization
- ALIGN Sample Alignment i
- 6T Magnet MAG-F
- CNCS Detector
- TOPAZ Detectors Phase I
- NOMAD Detectors Phase II
- POWGEN Detectors Side II
- SEQUOIA Detectors/collimator
- VULCAN-X Detector - Phase II
- SEQUOIA Brillouin scattering

Higher throughput      New Capabilities

# Research at SNS & HFIR supports Critical Areas for Basic Energy Research

## Science for Energy Applications

Fast Li-ion conductivity in new Thioborate Halides

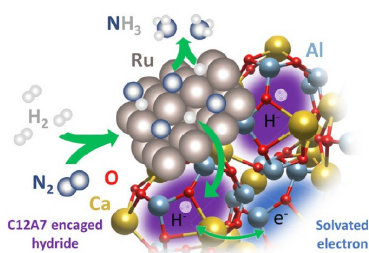


Neutron Powder Diffraction and pair distribution function measurements (SNS: NOMAD and POWGEN)



K. Kaup, *Angew. Chem. Int. Ed.* 2021

Understanding ammonia synthesis catalyzed by an electride



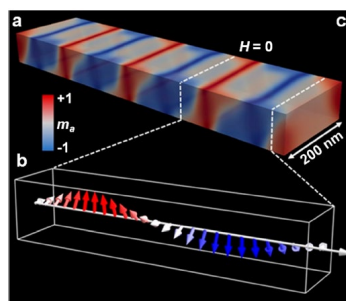
Neutron diffraction and spectroscopy (SNS: VISION and NOMAD)



J. Kammert et al., *JACS* 2020

## Matter for Energy and Information

Magnetic Field control of chiral domain walls

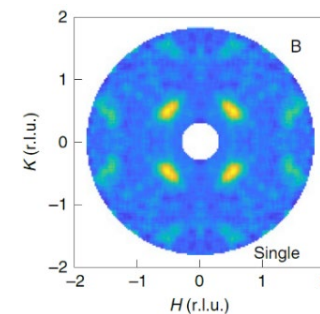


Small-angle neutron scattering (HFIR: GP-SANS)



S. Karna et al, *Nano Lett.* 2021

Materials for topological quantum computing ( $\text{Fe}_{1+y}\text{Te}_{1-x}\text{Se}_x$ )



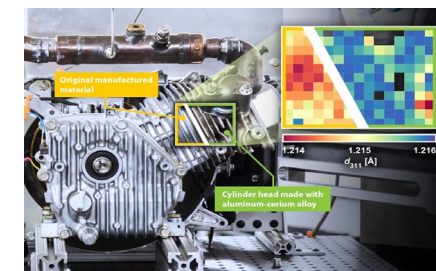
Polarized Neutron Scattering (SNS: HYSPEC)



Y. Li, *Nature Mater.* 2021

## Industrially-relevant Science for Sustainability

Operando strain measurements in additively manufactured engine components



Operando neutron diffraction (SNS: VULCAN)

A. Tremsin, *Additive Manufacturing* 2021

# SNS Upgrades

**PPU project:** Double the power of the existing accelerator structure

- First Target Station (FTS) is optimized for thermal neutrons
- Increases peak brightness of beams of pulsed neutrons
- Provides a platform for STS
- 2024 completion: 1.4MW -> 2MW on FTS



**STS project:** Build second target station with initial suite of beam lines

- Optimized for cold neutrons
- World-leading peak brightness
- Broader ranges of temporal and length scales, real-time measurements, smaller samples
- 2034 completion

# The eight STS project-constructed instruments address key science themes in the First Experiments Report

- Teams formed around 12 instrument concepts
  - 105 researchers from 63 institutions contributed to the science cases
  - 34 ORNL neutron scientists developed the technical concepts
- Eight instruments were selected based on the recommendation of a committee of 22 national and international experts
  - BWAVES – broadband spectrometer
  - CENTAUR – SANS/WANS
  - CHESS – cold neutron spectrometer
  - CUPID – neutron imaging
  - EXPANSE – wide-angle neutron spin echo
  - PIONEER – single-crystal diffractometer
  - QIKR – kinetics reflectometer
  - VERDI – polarized diffractometer



# SNS-FTS & HFIR: New Instruments in the Pipeline

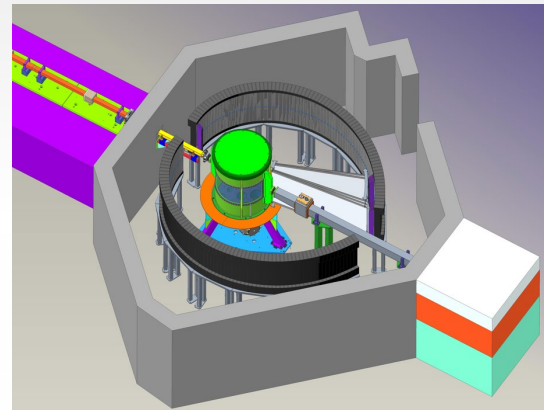
## VENUS

- Time-of-flight imaging
- Wholly new capabilities for complex materials e.g. additive manufacturing



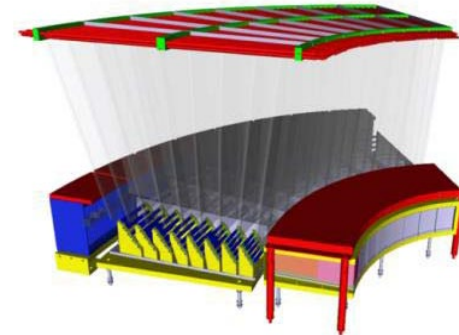
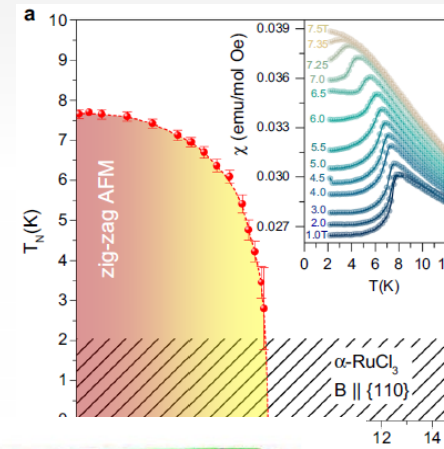
## DISCOVER

- Materials discovery diffractometer
- In-operando materials studies



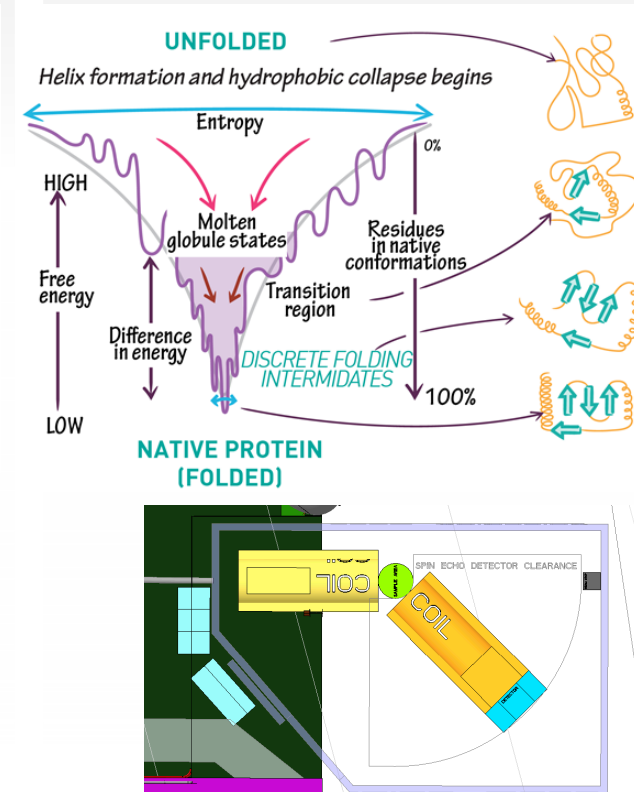
## MANTA

- Multi-Analyzer Triple Axis Spectrometer
- Quantum materials e.g. quantum spin liquids



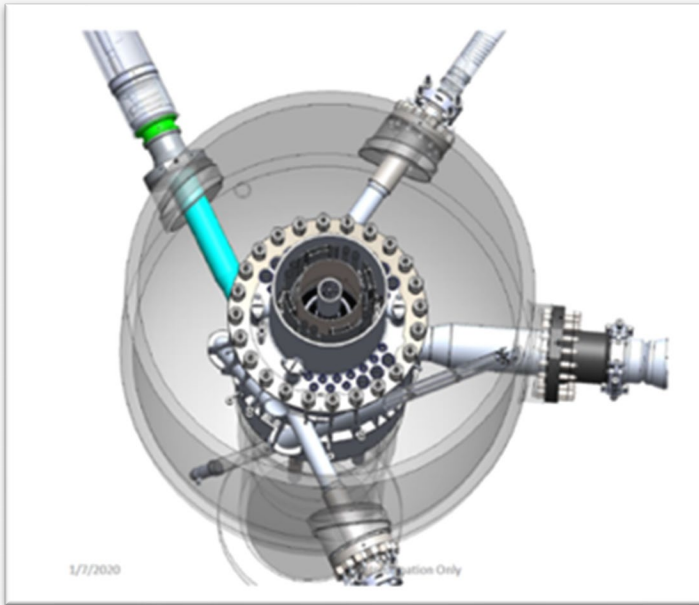
## High-Res Spin-Echo

- Entirely new energy window at ORNL
- Protein folding dynamics

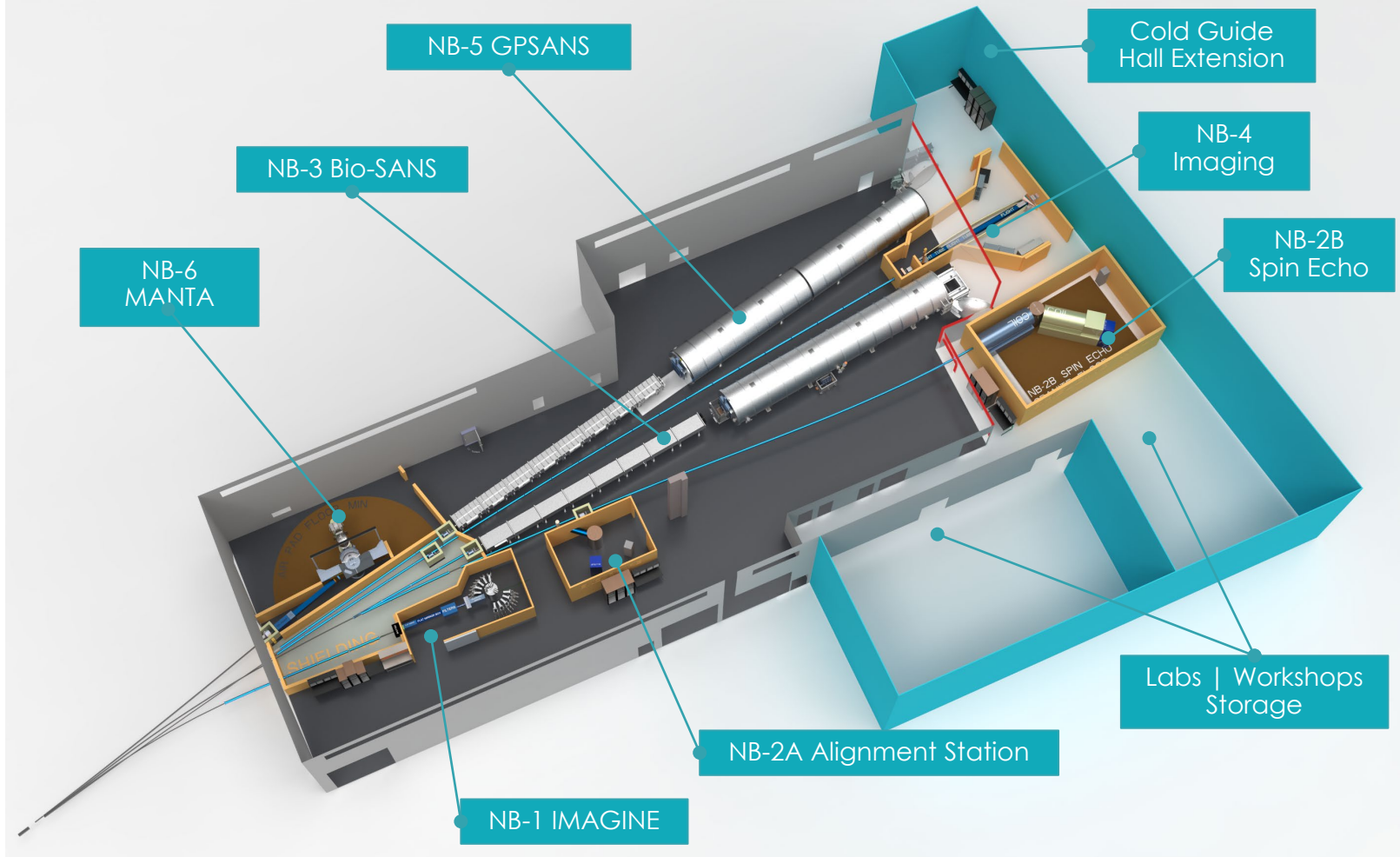


## Be Reflector & Beam Tubes

- New Be reflector design complete
- HB-4 tube assembly delivered



## Cold Guide Hall Upgrades



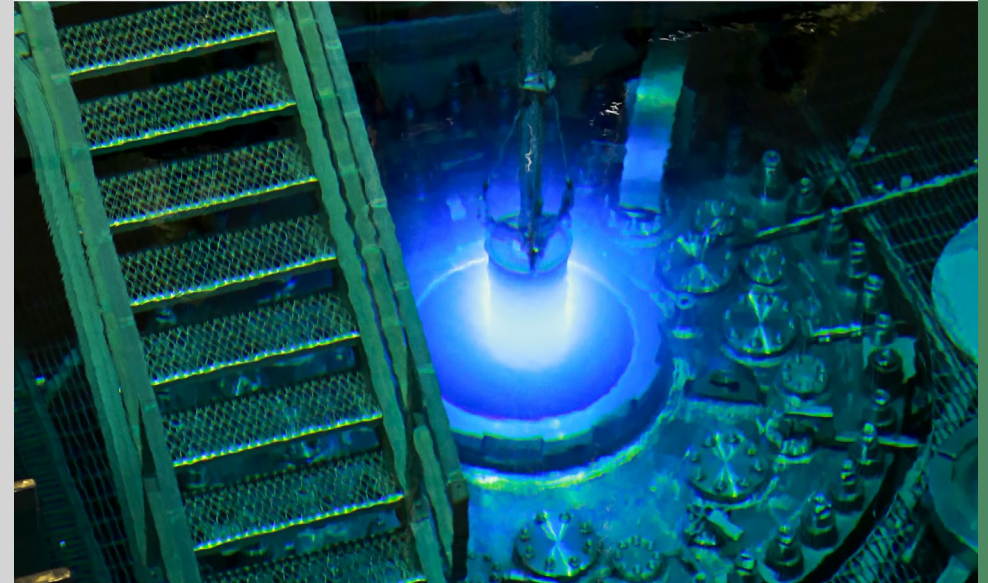


# HFIR Sustaining and Enhancing Neutron Science (SENSe)

- July 2020 BESAC Report recommends immediate pursuit of HFIR pressure vessel replacement and upgrades
- November 2020 CD-0 mission need approval for reactor pressure vessel replacement
- Opportunities currently being studied:
  - Upgrades to supporting infrastructure
  - Enabling future capability enhancements
  - Feasibility of combining with HBRR
- Sets the scene for potential major upgrade of HFIR science capabilities
  - Further enhancement of cold guide hall instruments
  - Thermal guide hall
  - Makes full use of HFIR's world-leading source brightness
- Positions HFIR for another 80 years of operation

*The Scientific Justification for a*

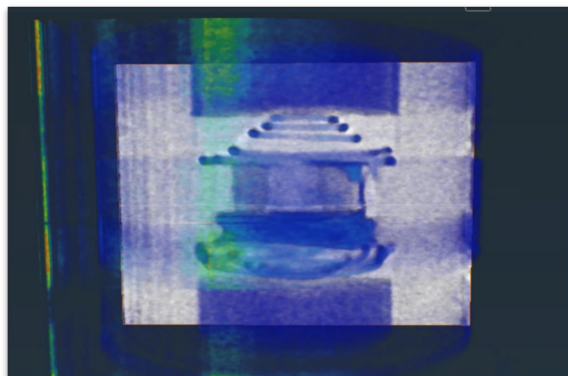
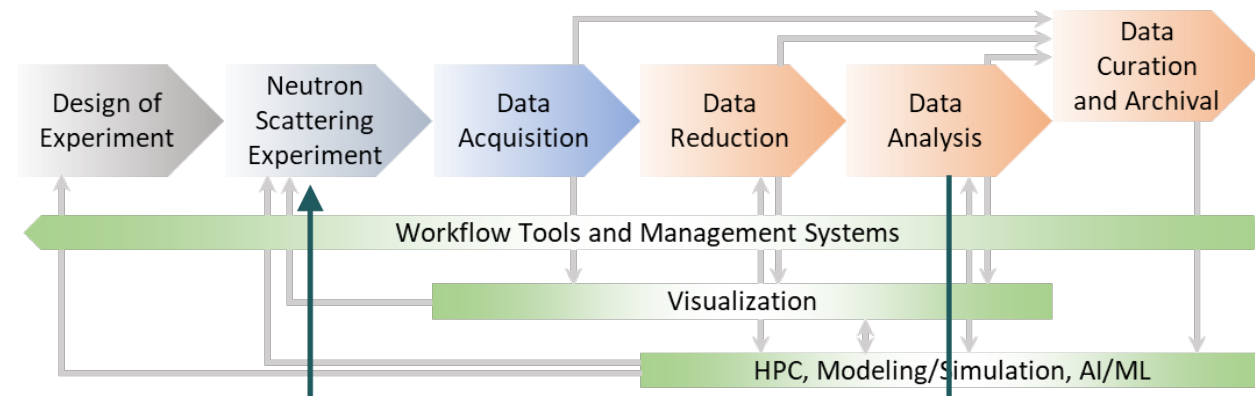
## U.S. Domestic High-Performance Reactor-based Research Facility



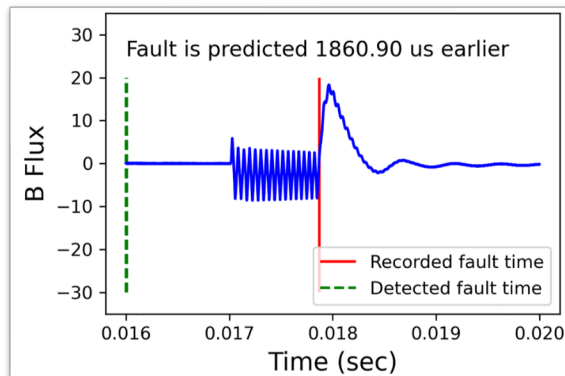
REPORT OF THE BASIC ENERGY SCIENCES ADVISORY COMMITTEE

# Software developments for data analysis and experiments

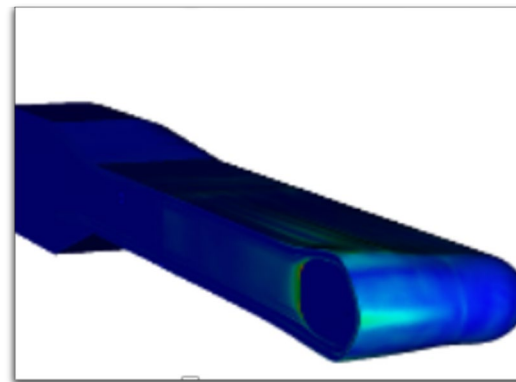
- Significant investments are being made to enable real-time data analysis to feed back into experimentation, with the goal of (semi)autonomous experiments
- AI/ML approaches are being integrated into data analysis as well as design and guidance of experiments



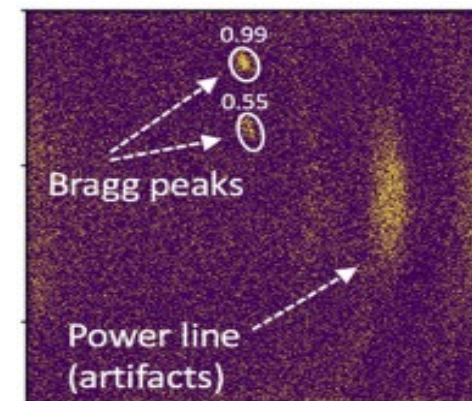
Successful demonstration of real-time decision-making during data collection using model-based image reconstruction; x4 improvement in speed (SNS: SNAP)



Successful demonstration of early detection of accelerator subsystem faults –high voltage equipment, and errant beam faults

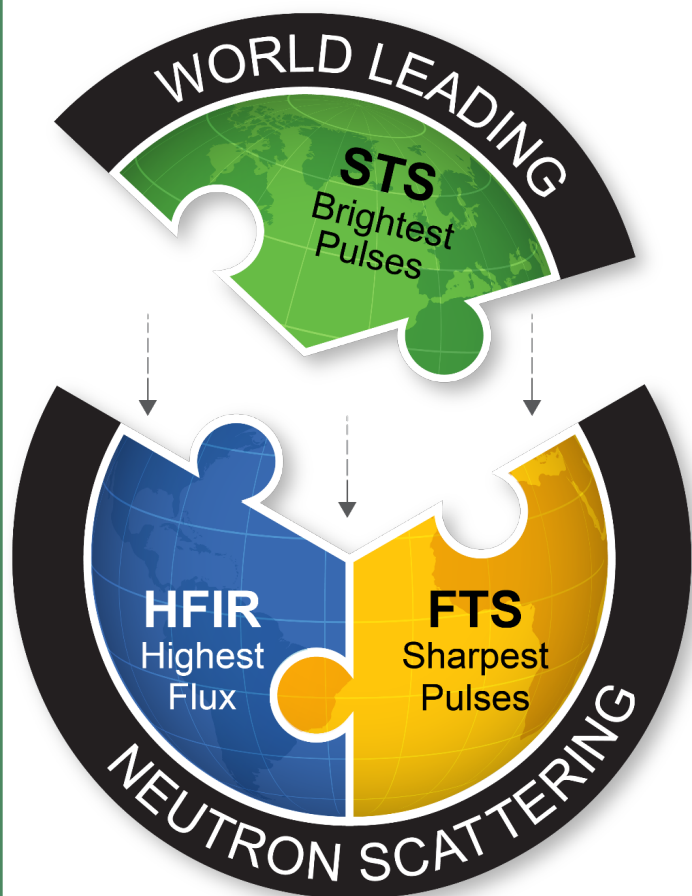


Development of surrogate models for strain prediction on high power targets during operation; simulations developed, installed on HPC to generate training data



Towards automated single crystal diffraction (HFIR: DEMAND) using region-based convolutional networks (R-CNN) to determine diffraction peaks

# Neutron Sciences Vision: 3-Source Strategy



HFIR	SNS FTS	SNS STS
Highest steady-state brightness of thermal and cold neutrons	Highest peak brightness of thermal neutrons	Highest peak brightness of cold neutrons
Monochromatic beams	High resolution	Small beams
Polarized beams	Focused bandwidth	Large bandwidth
Parametric studies	High-resolution crystallography	Hierarchical structures
Kinetics	Fast and high-energy dynamics	Materials discovery

# Thank you!

