

# NEUTRON SCATTERING FACILITIES AT THE OAK RIDGE NATIONAL LABORATORY HIGH FLUX ISOTOPE REACTOR

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## ABSTRACT

This paper will address four aspects of the neutron scattering science utilization of the High Flux Isotope Reactor (HFIR): 1) Since the last IGORR meeting, two instruments (IMAGINE- a single crystal diffractometer and a polarized beam station) have been declared operational. In addition, cold neutron beam line CG-1D has been fully devoted to imaging studies. One specific characteristic that will be discussed will be the neutron optics mirror system that has been used for the IMAGINE instrument in lieu of a conventional neutron guide. 2) For the last 15 years there has been a focused effort to fully utilize the open neutron beam positions at the High Flux Isotope Reactor (HFIR). With the addition of the new instruments and plans to build a new spin echo test station at beam port CG-4B we will have filled out all 16 presently available beam instrument positions. Therefore, at HFIR we are starting to shift our focus to major upgrades of existing instruments. Many of these instruments are now over 10 years old and new technology, including advances in neutron optics techniques, can provide significant increases in the utilization of the existing neutron beams. In addition, upgrades will allow the use of new sample environment equipment that is presently prohibited because of geometry restrictions. The plans for these upgrades and expected gains in performance will be discussed. 3) Another proposal to increase the utilization capabilities at HFIR is to build a new building next to the HB-4 cold neutron guidehall that would provide space for 9 lab facilities. These labs would include magnet, sample environment, polarization, and sample preparation support capabilities for the neutron scattering instruments. In addition, there is still a proposal being discussed with the United States Department of Energy to build a second moderator and guidehall tied to the HB-2 beam line at HFIR. The status of these two proposed major projects will be addressed. 4) Finally, the figure-of-merit for effectiveness of the utilization of the neutron scattering instruments at HFIR is measured by the number of users coming to the facility to use the instruments and the number of papers published related to experiments performed on the HFIR neutron scattering instruments. A summary of our self-evaluation of utilization for 2012 will be provided and compared with past years.

## 1. Introduction

As reported in IGORR papers in 2003, 2005, 2007, 2010, and 2012, a program was initiated just over 10 years ago to significantly improve the scientific capabilities and the neutron scattering instruments that could be supported by the four neutron beams at the Oak Ridge National Laboratory (ORNL) High Flux Isotope Reactor (HFIR). The purpose of this upgrade program was to create a world class neutron science research and user program based on continuous neutron beams that would be complimentary to the pulsed neutron beams of the Spallation Neutron Source Facility at ORNL. The initial upgrade objectives have been met and new objectives are being developed for a second upgrade program.

## 2. History and Description of the High Flux Isotope reactor

ORNL submitted a proposal for the construction of the HFIR to the Atomic Energy Commission in March 1959 and approval to proceed with construction was received in July of that year. The reactor design was completed in 1960 and construction began in June of 1961. Initial criticality was achieved on August 25, 1965 and full power normal operation (100 MW) was initiated in 1966. Since that time, the HFIR has operated for 449 fuel cycles (fuel cycle length of 21 to 27 days depending on the power level and experiments loaded in the core region).

Figure 1 provides a layout of the reactor core, beryllium reflector and the four beam tubes. At the present 85 MW full power operating condition the peak total neutron flux in the central flux trap for a typical target loading has been measured to be  $\sim 4.0 \times 10^{15}$  n/(cm<sup>2</sup>-s) with a thermal to nonthermal ratio of  $\sim 1.7$ . The peak thermal flux in the beryllium reflector is  $\sim 1.4 \times 10^{15}$  and occurs near the tips of the beam tubes. The neutron thermal to nonthermal ratio in the reflector ranges from around 1 to 30. There are three tangential beam tubes and one radial beam tube that start near the peak flux in the beryllium reflector and penetrate the reactor pressure vessel. The modifications to these four beam lines and the thermal and cold neutron instruments are the focus of the scientific upgrades that have been performed at the reactor facility.

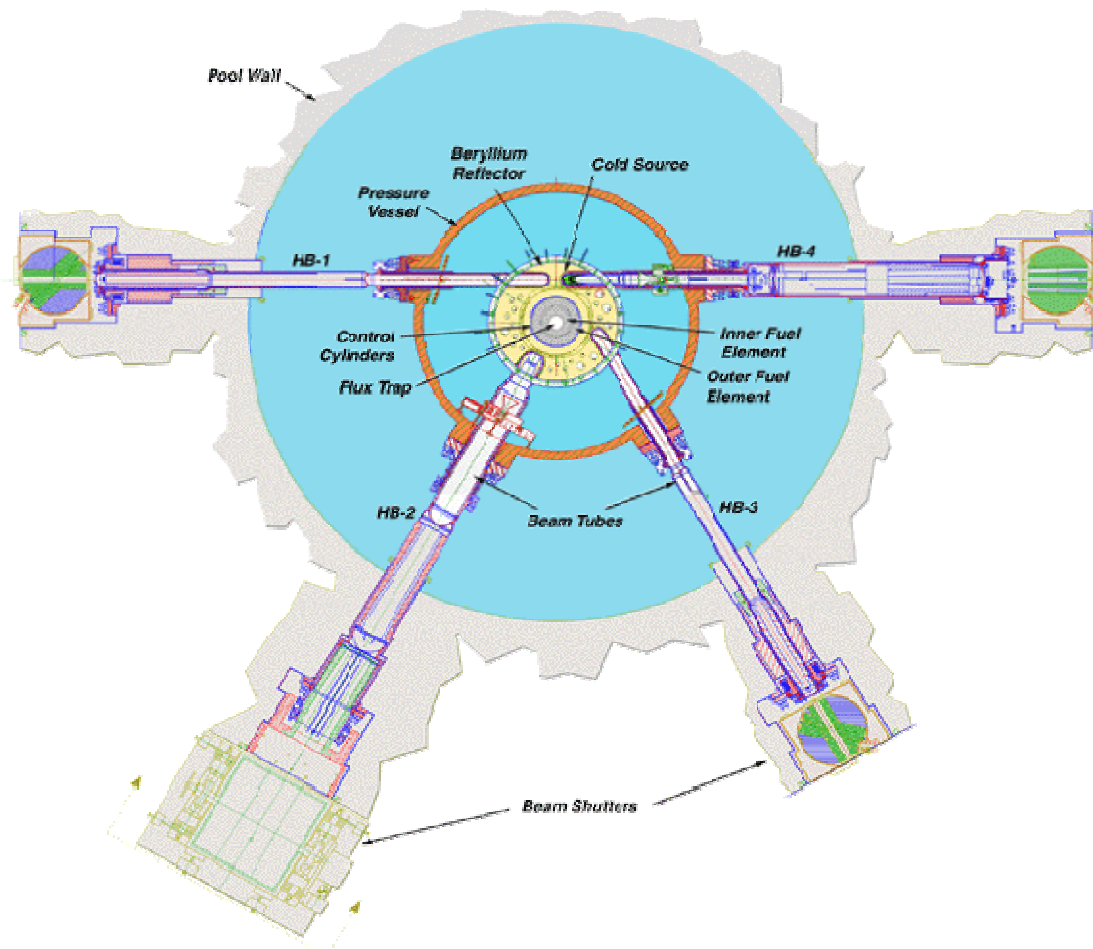


Figure 1: HFIR Reactor Core and Beam Tube Geometry

### 3. Present Status of Beamline Instruments

Figure 2 shows the present layout of instruments. Since the last IGORR meeting we have added a new polarized neutron beam development beamline at HB-2D, the previous CG-1D development beam line was converted to a full time neutron imaging station in the user program, and our new single crystal diffractometer IMAGINE instrument was installed, commissioned and transitioned to the user program. With these changes we now have 12 instruments in the user program, 3 beamlines devoted to development activities, and 2 potential locations for new beamline instruments.

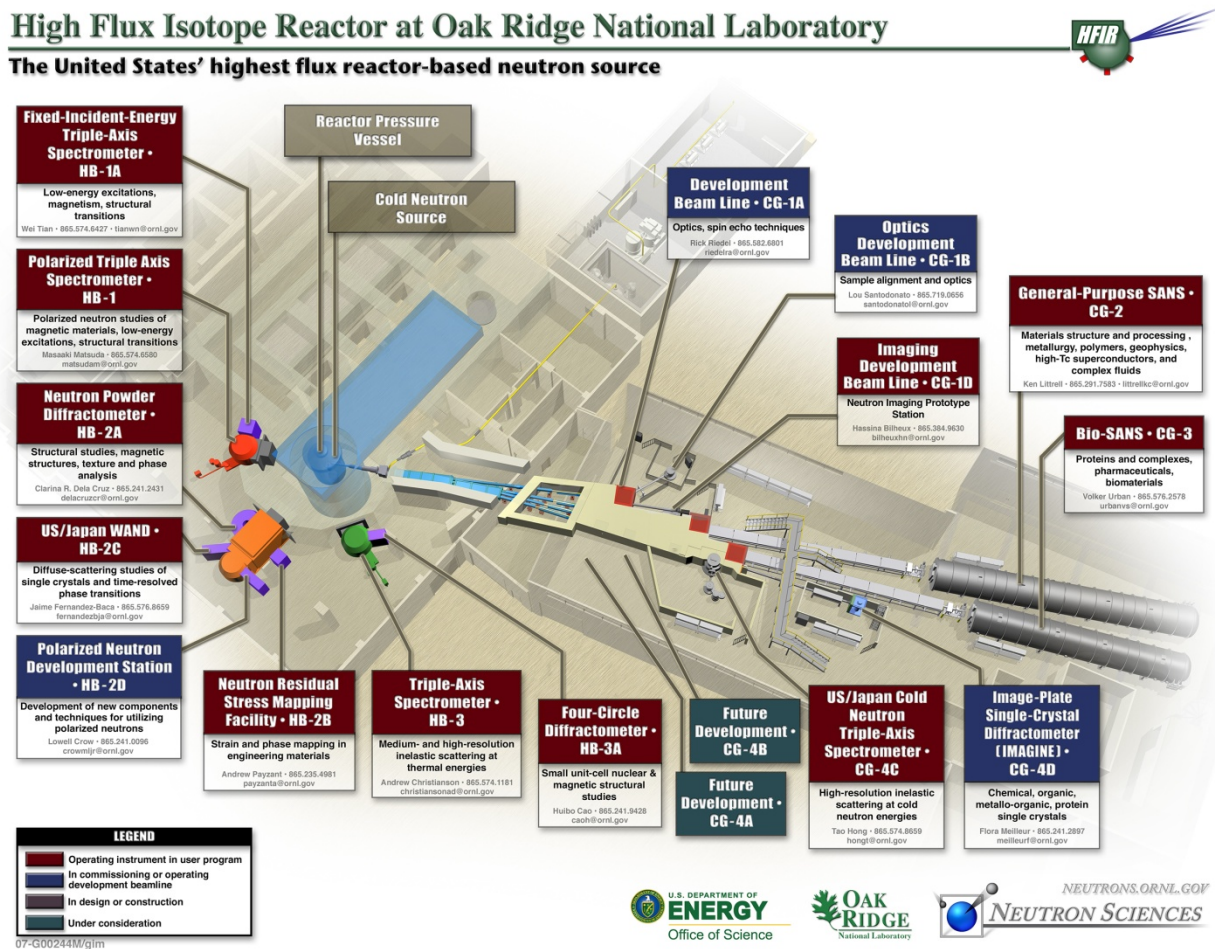


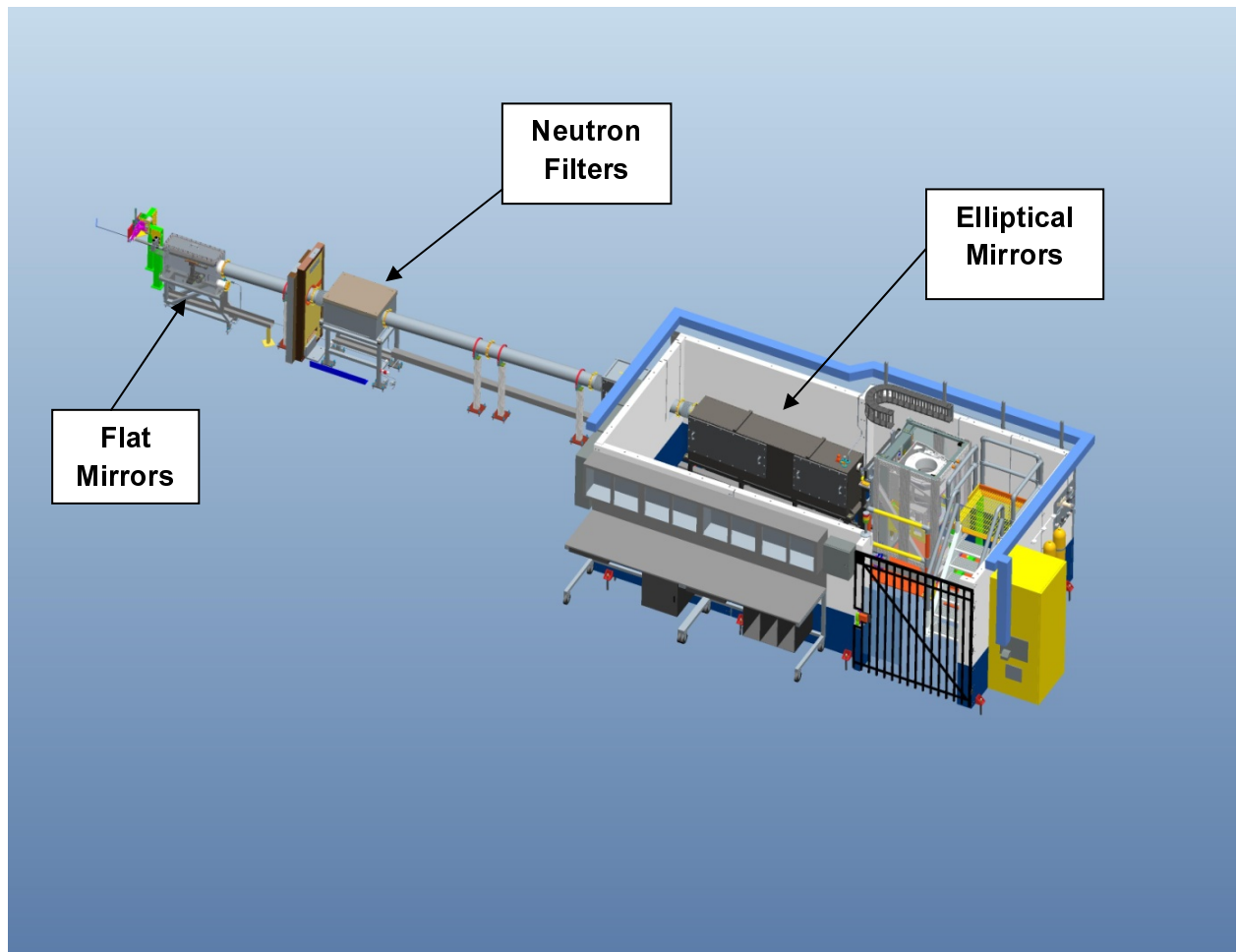
Figure 2: Reactor and Instrument Layout

### 4. New IMAGINE Instrument

The most significant event for the HFIR instrument suite since the last IGORR meeting was the completion of the installation and commissioning of the IMAGINE instrument. This instrument is used in the study of protein structure function (hydrogen atoms in proteins, enzymology, ligand complexes, and drug design); supramolecular crystallography (single-molecule magnets, metal-organic frameworks, and polyoxometalates); and materials chemistry (small molecules, minerals, and pharmaceuticals) [1]. Measurements have confirmed beam intensity, neutron beam bandwidth optics and focusing, and beam size meet the requirements specified at the beginning of the project. Approval was given to

transition from instrument commissioning to normal operation with users in June of this year. Scientific papers generated from experiments have already been submitted for publication.

One of the unique features of this beamline is its neutron optics system that uses elliptical mirrors, neutron filters and flat mirror options at different angles to the beam in a concept developed by the neutron optics group at ORNL to capture and focus the available neutrons at the sample position while maintaining an acceptable neutron divergence angle at the sample position. Figure 3 shows the layout of this system. Measurements performed during the commissioning activity confirmed that this system provided an improvement of at least a factor of 20 in beam intensity over a conventional neutron guide system [2].



**Figure 3: Layout of IMAGINE instrument**

## **5. Instrument Upgrades**

With the addition of the new instruments mentioned above and the plans to build a new spin echo test station at beam positions CG-4A and CG-4B, the focus at HFIR is shifting to major upgrades of existing instruments. The immediate plans are to rebuild the Wide Angle Neutron Diffractometer (WAND) instrument at HB-2C from the ground up (funded out of the US/Japan neutron scattering collaboration program), redesign the backend of the cold triple axis instrument at CG-4C, and redesign the backend of the thermal triple axis instrument at HB-3. These upgrades will focus on improving the detector acceptance angles and

decreasing detector background. These projects have been initiated and plans are to finish all three over the next 2 years.

## 6. Future Facilities

Two major facilities are presently being planned for the HFIR. The first is a facility that would be built adjacent to the existing HB-4 cold neutron guidehall that would provide 9 laboratories. This 465 m<sup>2</sup> facility would provide new lab spaces that would include a cryogenics lab, magnet lab, high temperature lab, polarization lab, bio-sciences lab, and laser lab.

The second facility being planned for HFIR is a second guide hall driven by a new cold and/or thermal moderator on the HB-2 beam line. This is the largest beam available at HFIR and could produce neutron beams for as many as 9 instruments in a new guidehall. Figure 4 shows a conceptual layout of the proposed new guidehall. This guidehall would be significantly larger than the existing guidehall and would nearly double the number of instruments in the user program for HFIR. Improved optics and the space to extend the neutron guides into the beam tube would provide a significant improvement (factor of 3 or more) in beam intensity over that presently available in the existing guidehall. The present focus is the optimization of the moderator concept geometry to meet the anticipated scientific needs.

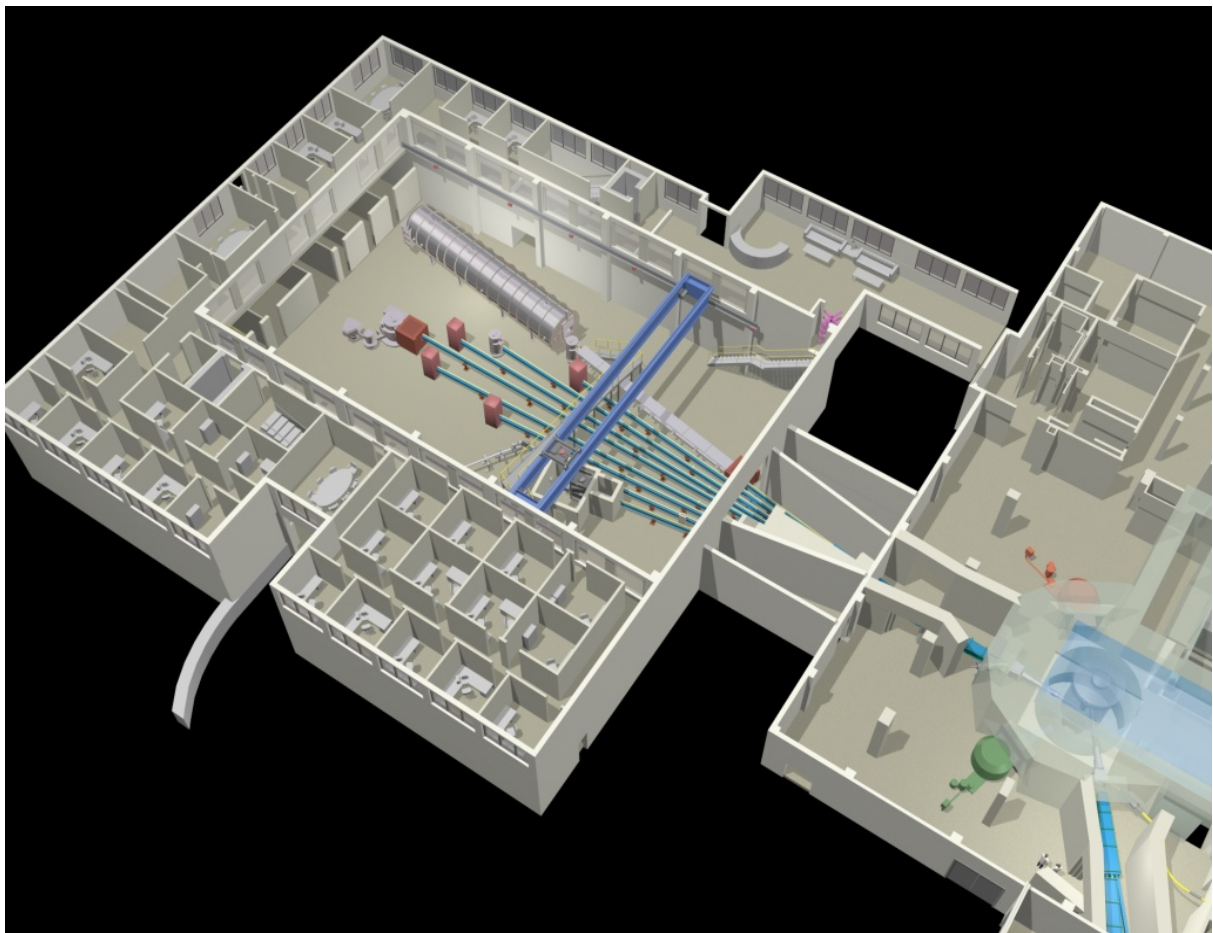
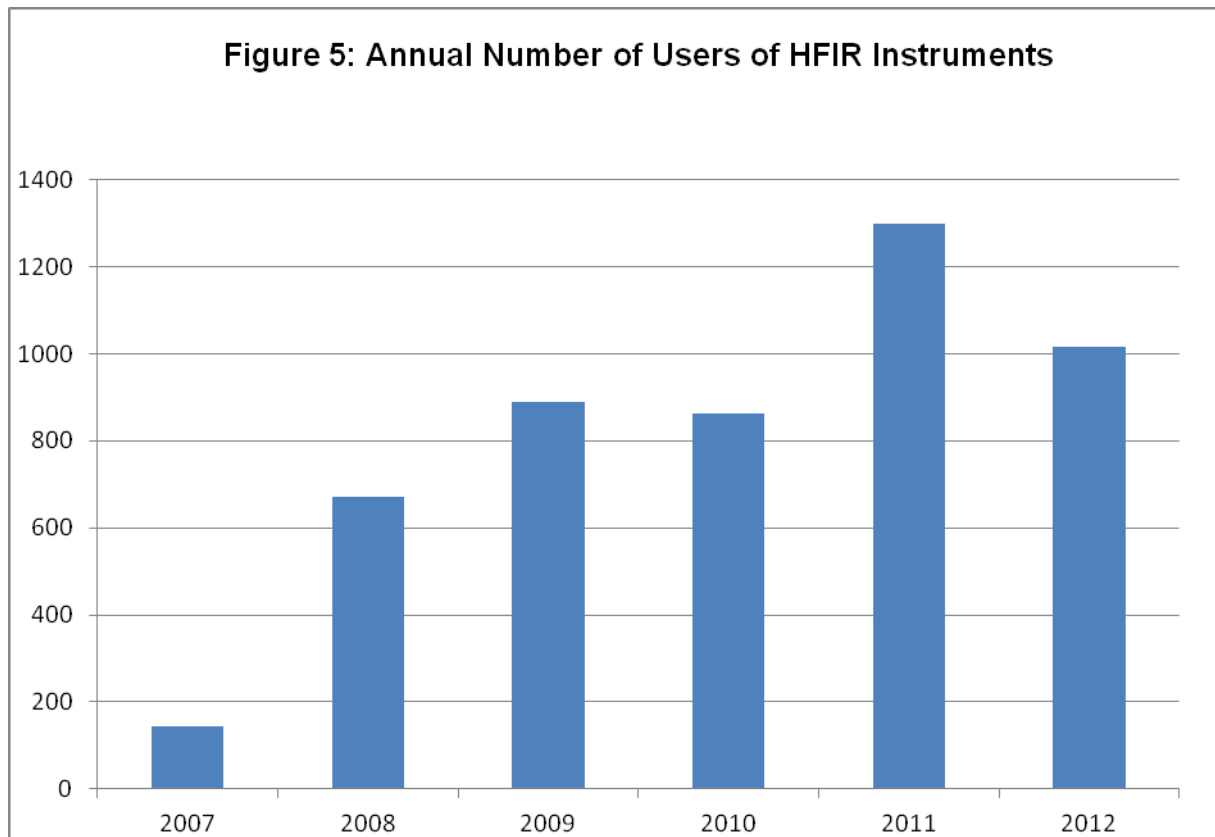


Figure 4: Proposed New HB-2 Guidehall for HFIR

## 7. Utilization of Neutron beams

Two measures of the utilization of the HFIR neutron scattering instruments are the number of users and the number of publications tied to experiments performed using the beam line instruments. Figure 5 is a plot over the last six years of the number of users within the DOE user program at HFIR for neutron scattering instruments [3]. This data shows the rapid rise from the start of the user program at HFIR from a couple hundred users to more than a thousand users per year. The number of publications tied to HFIR neutron scattering instruments has seen a similar increasing trend rising from 39 publications in 2008 to 129 publications in 2012 [4].



<sup>1</sup>IMAGINE instrument presentation given by Flora Meilleur to the HFIR Instrument Configuration Control Committee (June 2013)

<sup>2</sup>Personnal communication from Lee Robertson Oak Ridge National Laboratory (August 2013)

<sup>3</sup>Personnal communication from Robbie DeJarnette (Oak Ridge National Laboratory (August 2013)

<sup>4</sup>Personnal communication from Allen Ekkebus (Oak Ridge National Laboratory (August 2013)