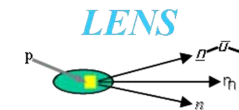




# The Low Energy Neutron Source (LENS) –

## A University Based Pulsed Neutron Source For Collaborative Research

D.V. Baxter, V. P. Derenchuk, H. Kaiser, M. Leuschner, M.A. Lone, H.O. Meyer, H. Nann, T. Rinckel, W.M. Snow, P. Sokol, C. M. Lavelle, N. B. Remmes, Y. Shin



### Overview

The Low Energy Neutron Source (LENS) will be the first university-based pulsed neutron source in the U.S. By utilizing low energy (p,n) reactions in a beryllium target coupled to a light water reflector and cold methane moderator, LENS is expected to produce time-averaged thermal neutron fluxes suitable for neutron scattering and development of instrumentation. The facility is seen as playing a role similar to that played by many of the national-scale research reactors in Europe. It has a three fold mission to perform research with neutrons, educate students in neutron science and develop new neutron instrumentation and technology. It will also provide support to nuclear physics at IUCF through commissioning assistance with aCORN as well as in the development of ultra-cold neutron sources.

Initially, LENS will have three different beam lines, one for Small Angle Neutron Scattering (SANS), one for radiography, and one devoted to the development of novel instrumentation. The low proton energy used in LENS yields limited activation in the source (compared to spallation or reactor sources), making this facility ideal for technical studies of neutron moderation and a variety of educational programs. The variable pulse length will facilitate investigation of long-pulse instrumentation concepts.

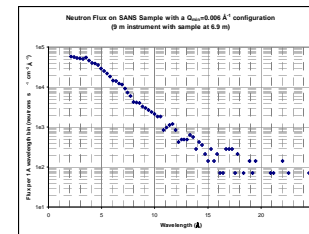
The low energy of the proton beam provides a lower average primary neutron energy, reduced power input into the moderator, and reduced radiation damage in the moderator material. These features make it feasible to operate the moderator at low temperature (below 10K), giving a colder neutron spectrum for scattering and opening up opportunities for developing new moderator materials and designs, including new premoderators for ultra-cold neutron converters. The first neutrons from LENS are anticipated by December 2004 with full design power expected by the Fall of 2006.

### Neutron Radiation Effects Research Program (NRERP)

A second target station will be optimized to provide neutrons for radiation effects testing on materials and devices. NRERP will provide a neutron spectrum that accurately simulates the atmospheric neutron spectrum. Atmospheric neutrons are becoming an increasingly troublesome problem for microelectronics as device sizes continue to shrink. NRERP is a natural complement to the existing RERP user facility here at IU, which utilizes the 200 MeV protons from the IU cyclotron to simulate space radiation environments.

### Small Angle Neutron Scattering:

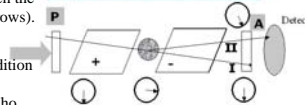
The SANS instrument will be LENS's first operational scattering instrument. The target to detector instrument length will be adjustable from approximately 7 m to 10 m with a Q range of approximately  $0.006 \text{ \AA}^{-1}$  to  $0.5 \text{ \AA}^{-1}$ . Monte Carlo simulations of the instrument are being run using VITESS utilizing the TMR spectrum from MCNP models. Such simulations have shown that with a minimum available Q of  $0.006 \text{ \AA}^{-1}$  on a 9 m instrument, the cold ( $>2\text{\AA}$ ) neutron flux on the sample exceeds  $1 \times 10^5 \text{ n s}^{-1} \text{ cm}^{-2}$  for a 13 MeV and 32 kW proton beam.



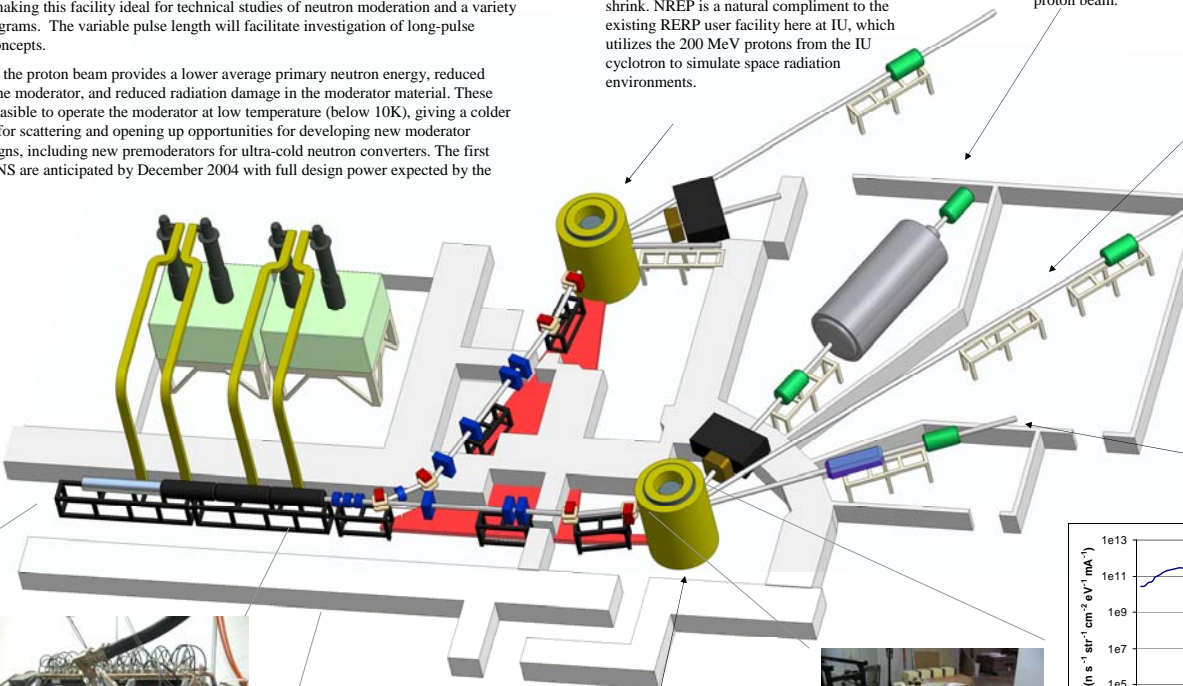
### Spin Echo Scattering Angle Measurement (SESAME):

The first novel instrument to be developed at LENS is one that uses the neutron spin to encode momentum transfer information. This can be done with far greater precision than is possible in conventional instruments. For instance, in Spin-Echo SANS mode (see figure on the right), a polarized (P) neutron beam passes through a magnetic field (+) in which the polarization precesses (indicated schematically by the arrows). For unscattered neutrons, this precession is reversed in a subsequent field region (-), producing a "spin-echo" condition for all unscattered neutrons, independent of their initial trajectory. Neutrons that scatter in the sample will not echo, and therefore can be detected on the far side of the analyzer (A).

### Spin Echo SANS



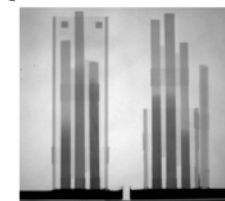
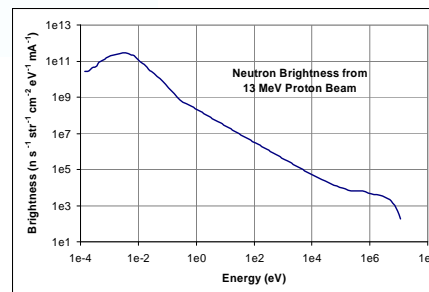
This technique allows one to probe length scales more than an order of magnitude larger than with the SANS instrument and to do so with a significantly greater neutron flux. Variations on this geometry can be used for high resolution diffraction (10-100ppm) or to separate diffuse and specular scattering in reflectometry.



### The Target-Moderator-Reflector (TMR)

Intensive simulation development of the LENS/TMR geometry has produced a model for a source of cold and thermal neutrons that is both highly efficient and intense while remaining low in background neutrons. Optimization was done using the MCNP series of Monte Carlo codes.

The moderator is tightly coupled to the Be source through a slab geometry and 50 cm diameter water reflector. The thermal load on the target is limited by inclining the beam at  $45^\circ$ , a geometry that also reduces the fast neutron flux in the SANS and  $\Psi$  beam lines. The reflector is separated from the shielding layers by a borated decoupler to limit activation of the primary lead gamma shield. The plot shows the intensity from our 12x12x1 cm methane moderator at 22K. One ongoing research project is to develop kernels suitable for conducting these simulations at the lower temperatures at which we expect to operate.



Neutron Radiographs of Indiana Limestone (taken at NEUTRA)

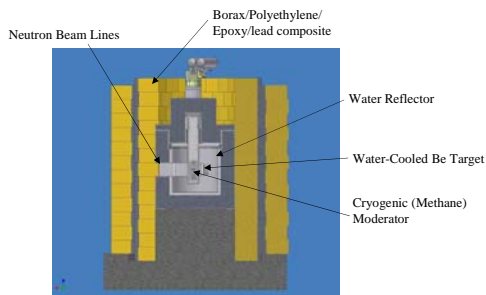
### Neutron Radiography

The neutron radiography beam line is a pinhole camera for neutrons. By using a 2 cm diameter pinhole and an adjustable pinhole-to-image length (from 3 m to 10 m), the radiography beam line will be able to provide images comparable to those shown (taken at the NEUTRA channel at PSI in Switzerland), though the exposure time required increases substantially over the exposure time at NEUTRA.

In addition, by effectively imaging the neutron source, the neutron radiography line will provide a crucial diagnostic tool for moderator development.

### The Proton Delivery System:

The initial proton delivery system (Phase I) will provide a 10 mA (peak current), 7 MeV beam with a 0.2% duty cycle by utilizing a PL-7 LINAC. Upgrades planned over the 2005-2006 calendar years will increase this to over 50 mA (peak current) with a 5% duty factor and an energy that may be as high as 13 MeV. The beam will have a variable pulse width ranging from about 5  $\mu$ s to 1.0 ms or more.



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