FP12 Pulsed Cold Neutron Beam Line for Fundamental Nuclear Physics at LANSCE

P.-N. Seo[1*], J. D. Bowman[1], M. Dabaghyan[2], M. Gericke[1,3], R. C. Gillis[4],
G. L. Greene[5,6], M. B. Leuschner[3], J. Long[1], R. Mahurin[6], G. S. Mitchell[1],
H. Nann[3], S. A. Page[4], S. I. Penttila[1], G. Peralta[1], W. D. Ramsay[7], S. Santra[3],
E. I. Sharapov[8], and W. S. Wilburn[1]

[1]*Los Alamos National Laboratory, Los Alamos, NM 87545, USA*
[2]*Department of Physics, University of New Hampshire, Durham, NH 03824, USA*
[3]*Indiana University, Bloomington, IN 47405, USA*
[4]*University of Manitoba, Winnipeg, MB R3T2N2, Canada*
[5]*Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA*
[6]*University of Tennessee, Knoxville, TN 37996, USA*
[7]*TRIUMF, 4004 Wesbrook Mall, Vancouver, British Columbia V6T2A3, Canada*
[8]*Joint Institute for Nuclear Research, Dubna, Russia*

Abstract. A new pulsed cold neutron beam line, flight path 12, has been commissioned at LANSCE by the NPDGamma collaboration. The beam line was designed for fundamental nuclear physics experiments. We present the measured brightness of the unique backscattering moderator viewed by the flight path 12 neutron guide and report results for guide performance measurements. The peak neutron flux out of the guide is $dN/dE = 2.4\times10^5$ neutrons/meV/cm^2/s/μA at 2 meV neutron energy.

INTRODUCTION

The NPDGamma collaboration has commissioned a new pulsed cold neutron beam line, flight path 12 (FP12), at Los Alamos Neutron Science Center (LANSCE). The beam line is designated for basic nuclear physics research. The 21-m long flight path consists of a shutter, two frame-definition choppers, and a m=3 supermirror neutron guide. The pulsed nature of the neutron beam produced by a narrow proton pulse provides an accurate neutron energy information through a time-of-flight (TOF) measurement and thus a possibility to control systematic errors in experiments to a new level of precision. The first experiment on the beam line is NPDGamma, which is under commissioning [1,2]. This experiment will determine the weak pion-nucleon coupling constant by measuring the parity-violating directional gamma-ray asymmetry A_γ with respect to the neutron spin when polarized cold neutrons capture in liquid para-hydrogen. A_γ is expected to be small ~ $-5\text{x}10^{-8}$. The NPDGamma experiment with the cold neutron flux of FP12 can measure A_γ to an uncertainty of 5×10^{-8} in a year.

FP12 BACKSCATTERING MODERATOR

From the LANSCE linear accelerator 800-MeV H^- beam pulses are injected into the Proton Storage Ring (PSR). As a part of the injection process, the H^- particles are stripped to H^+. In the PSR the protons are accumulated and compressed into pulses with a roughly triangular shape, 250-ns wide at the base. The proton pulses are then extracted to a tungsten neutron production target at the rate of 20 Hz and with average

---

[*] Present address: [1]*Department of Physics, North Carolina State University, Raleigh, NC 27695, USA*

CP769, *International Conference on Nuclear Data for Science and Technology,*
edited by R. C. Haight, M. B. Chadwick, T. Kawano, and P. Talou

current of 100-150 µA [3]. Fast neutrons from the spallation process are thermalized by the FP12 cold-hydrogen moderator operated with supercritical hydrogen gas. Only the new FP12 and FP13 neutron guides are viewing this unique partially decoupled cold hydrogen moderator operated in a backscattering and flux-trapped geometry [4]. The 12x12 cm^2 surface area of the moderator is perpendicular to the FP12.

The important source performance quantity is the moderator brightness that has been calculated [5] and then, the first time, measured by the NPDGamma collaboration. The measurement was done with a novel two-pinhole collimator system using a ^{6}Li-loaded scintillation neutron detector. The measurement and result are described in detail in [6]. Figure 1 shows the measured brightness that has a maximum of 1.3x10^8 n/s/cm^2/sr/meV/µA with 7.1% uncertainty at 3-meV neutron energy.

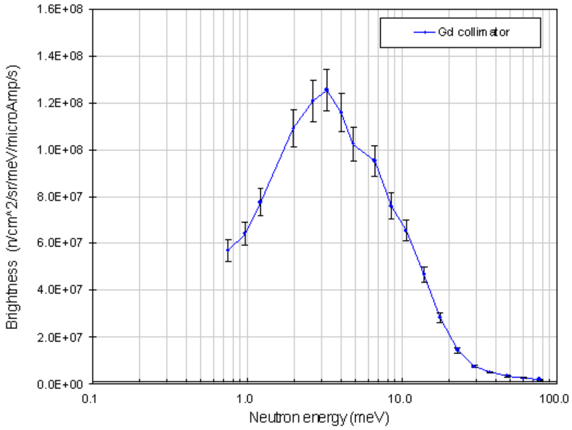

FIGURE 1. Measured brightness of the cold hydrogen moderator viewed by the FP12 neutron guide.

A neutron pulse from the moderator has a shape with two time constants. During the moderation process, neutrons in a thermal energy range experience more than one collision with hydrogen molecules in the moderator and with particles in the Be-reflector surrounding the moderator. The shorter time constant, ~250 µs, is related to the hydrogen moderation and the longer time constant, ~600 µs, is caused by the Be-reflector. When the neutron energy decreases, more neutrons have the longer time constant [7].

FP12 *m*=3 NEUTRON GUIDE

Neutrons from the moderator enter the 21 m long straight $m=\theta_c/\theta_c(^{nat}\mathrm{Ni})=3$ super mirror neutron guide with the inner cross section of 9.5x9.5 cm^2. The transmission of the guide is based on the total reflection of neutrons on the inner surfaces of the guide coated with a number of nickel and titanium layers. The reflectivity of every 50-cm long guide element was verified with 4.27-Å neutrons by the manufacturer and was shown to be better than 85% for a glancing angle *m*=3 [6,8].

For guide performance studies we measured the reflectivity of the assembled guide system with the two-pinhole collimator [6]. The upstream pinhole was mounted on the axis of the beam next to the guide exit window. The downstream pinhole collimator with a ^{6}Li-loaded scintillator, located 220 cm downstream from the first pinhole, was scanned across the beam. Figure 2 shows a plot of 3-meV (5.3-Å) neutrons as a function of the distance of the downstream pinhole from the beam axis. Each peak in the plot represents a different number of reflections in the guide before detection. The distance of a peak from the beam axis gives the neutron glancing angle in the guide. From the results of the vertical and horizontal scans an average guide reflectivity was deduced with the result shown in Fig. 3. The neutron reflectivity is plotted as a function of the perpendicular neutron velocity component $v_\perp$ to the guide surface. The dashed line is a measured reflectivity of one of 50-cm long guide elements performed by the manufacturer using 4.27-Å neutrons. Up to $v_\perp$= 7 m/s corresponding to $m\approx1$, the reflectivity is about one and then it starts linearly to decrease to ~ 0.85 at $v_\perp$ = 21 m/s which corresponds to the glancing angle of *m*=3. After *m*=3 the reflectivity drops quickly to zero. The measured (using 5.3-Å neutrons) reflectivity of the assembled guide (three points with error bars) decreases faster than the

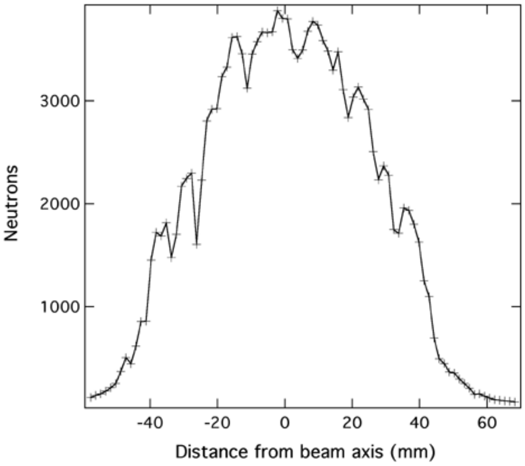

FIGURE 2. Number of 3-meV neutrons as a function of the distance of the downstream pinhole from the beam axis. Measurements were done with a 2.4-ms gate width and collecting 200 proton pulses in each position.

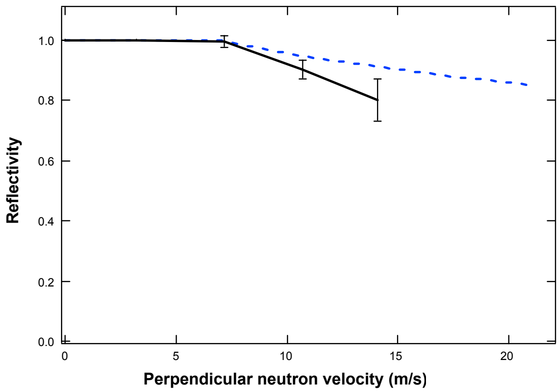

FIGURE 3. The dashed line gives the measured neutron reflectivity of a single guide element as a function of the neutron velocity component perpendicular to the guide surface. The solid line gives the measured reflectivity of the assembled 21 m long guide system. This is an average reflectivity over all 39 guide elements.

reflectivity of the single guide element indicating that some of the 39 guide elements are not perfectly aligned with respect to each other. Thus the reflected neutrons do not end under the correct peak seen in Fig. 2 but still are exiting the guide with slightly different angle.

NEUTRON FLUX IN FP12

Based on the measured moderator brightness and the guide reflectivity we calculated neutron flux out of the FP12 guide. The neutron flux is plotted in Fig. 4 as a function of neutron time of flight (top) and energy (bottom). The peak neutron flux is d*N*/d*E*= $2.4\text{x}10^5$ neutrons/meV/cm^2/s/μA at 2 meV neutron energy. The neutron flux was also measured using neutron beam monitors, a ^{3}He ion chamber. The calculated and measured fluxes agree at the 10% level.

The instantaneous neutron rates at the end of the guide are very high. At around TOF = 15 ms a rate of 20 GHz can be obtained with 100 μA proton current. This rate is too high for neutron counting detection and therefore, current mode detection has to be applied [2]. This challenge will be more serious at SNS where the neutron rates are an order of magnitude higher.

FRAME-DEFINITION CHOPPERS

The beam line is equipped with two rotating frame-definition choppers located at 9.38 m from the moderator surface. The choppers are used to define the TOF range of interest and to prevent low-energy neutrons from the previous frame to enter the new frame and thus mix neutrons with different energies. To block undesired neutrons the chopper aluminum plates were plasma coated with a thick layer of Gd_2O_3, which starts to be black for 30-meV neutrons. The diameter of the chopper plates is 1024 mm. Each chopper plate has a 109° cut for the beam to pass. Performance of the frame definition chopper is shown in Fig. 5 where TOF spectra measured by a ^{3}He beam monitor mounted on the end of the guide are shown. The beam aperture in the chopper starts to open at TOF=0 ms, is fully open at 4 ms, and starts to close at 30 ms. The full length of the time-of-flight frame is 50 ms. The last 10 ms in this measurement is used by DAQ to transfer data. The spectrum (solid line) was measured with the chopper-off and thus, neutrons from the previous frame were detected. A spectrum (dashed line) was taken with the chopper running and phased to the T_0, the main facility timing signal. The spectrum (dotted-and-dashed line) shows the contribution of slow neutrons from the previous frame when the chopper is not running. The fast neutron part of the spectrum was not detected because of the small n-^{3}He absorption cross section for fast neutrons, and small ^{3}He thickness in the monitor. With the two

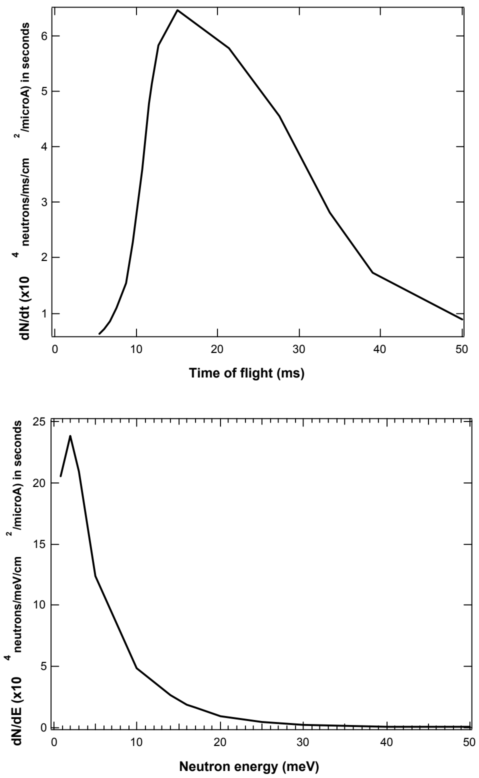

FIGURE 4. Calculated neutron flux out of the FP12 guide as a function of neutron time-of-flight (top) and energy (bottom).

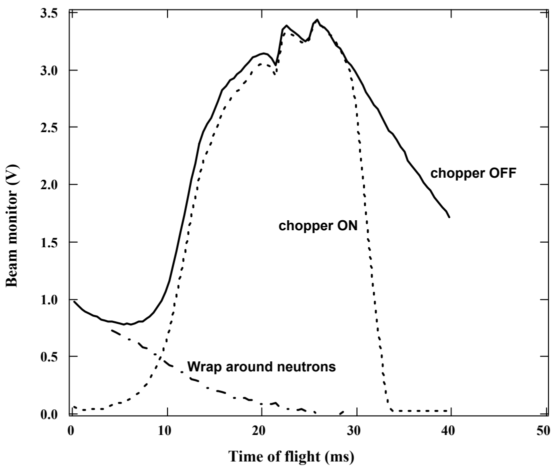

FIGURE 5. Time-of-flight neutron spectra measured by a ^{3}He ion chamber at the end of the neutron guide. The solid line gives the neutron spectrum with the chopper-off. The dashed line spectrum shows neutrons when the chopper is on and phased to the T_0. Under the dotted-and-dashed line is the contribution of slow neutrons from the previous frame when the chopper is not running.

independent choppers any length of the time-of-flight period shorter than 26 ms can be selected.

The choppers are tightly phased to the facility master-timing-reference which in turn is referenced to the power grid. Same timing is used for the proton extraction from the PSR. The chopper feedback loop keeps the chopper phased to the T_0 to 50 μs or better. In the NPDGamma experiment the chopper-closed part of the TOF spectrum, after 34 ms, is used to study detector pedestals and backgrounds.

SUMMARY

New high precision fundamental neutron physics experiments can be designed to take advantage of the features of the new pulsed cold neutron beam line FP12 at LANSCE. The beam line is equipped with a $m = 3$ supermirror neutron guide with a 9.5x9.5 cm^2 inner cross section. The neutron flux has a peak of $dN/dE = 2.4\text{x}10^5$ neutrons/meV/cm^2/s/μA at 2 meV. Because of the pulse nature of the beam the neutron energy can be determined accurately through a time-of-flight measurement that allows control of sources of systematic errors to a new level of precision.

ACKNOWLEDGMENTS

This work was supported in part by the U.S. Department of Energy (Office of Energy Research, under Contract W-7405-ENG-36), the National Science Foundation (Grant No. PHY-0100348), the National Sciences and Engineering Research Council of Canada.

REFERENCES

1. P.-N. Seo *et al.*, *in these proceedings*; W. M. Snow *et al., Nucl. Instrum. Methods* A **440**, 729 (2000).
2. M. T. Gericke *et al.*, "A Low-Noise CsI Detector Array for the Precision Measurement of Parity Nonconservation in $\vec{n} + p \rightarrow d + \gamma$," in *International Conference on Nuclear Data for Science and Technology 2004*, AIP Conference Proceedings (Melville, New York, 2005).
3. P. W. Lisowski *et al.*, *Nucl. Sci. Eng.* **106**, 208 (1990).
4. G. J. Russell *et al.*, in *Proceedings of the 16th Meeting of the International Collaboration on Advanced Neutron Sources*, Dusseldorf-Neuss, Germany, p. 833 (2003).
5. G. Muhrer *et al.*, *LANL Report* LA-UR-00-6078 (2000).
6. P.-N. Seo *et al., Nucl. Instrum. Methods* A **517**, 285 (2004).
7. E. Sharapov, private communication; M. Russina et al., *Proceedings of the 16th Meeting of the International Collaboration on Advanced Neutron Sources*, Dusseldorf-Neuss, Germany, p. 667 (2003).
8. Mirroton LTD., 1121 Budapest, Konkoly Thege ut 29-33, Hungary.