PP#-80-077

ORO#-2504-309

# MEASUREMENT OF ULTRACOLD NEUTRONS PRODUCED BY USING DOPPLER-SHIFTED BRAGG REFLECTION AT A PULSED-NEUTRON SOURCE

T.O. Brun, J.M. Carpenter, V.E. Krohn, and G.R. Ringo

Argonne National Laboratory, Argonne, Illinois 60439

and

J.W. Cronin

University of Chicago, Chicago, Illinois 60637

and

T.W. Dombeck, and J.W. Lynn

University of Maryland, College Park, Maryland 20742

and

S.A. Werner

University of Missouri, Columbia, Missouri 65201

Ultracold neutrons (UCN) have been produced at the Argonne pulsed-neutron source by the Doppler shift of 400-m/s neutrons Bragg reflected from a moving crystal. The peak density of UCN produced at the crystal exceeds 0.1 n/cm$^3$.

## DISCLAIMER

Methods of producing ultracold neutrons (UCN) have aroused considerable interest in recent years as potentially providing a means to carry out a precise search for the electric dipole moment of the neutron [1]. It was shown in a previous publication [2] that the density of UCN that can be stored in a bottle is limited by the peak neutron density in a pulsed source and not by the time-averaged density. For this reason pulsed-neutron sources are very attractive for the production of UCN as the peak density can be much higher than at the highest flux steady state reactors.

This letter describes the operation of a new type of UCN source which utilizes Bragg reflection from a moving crystal to Doppler shift cold neutrons ($\sim$400 m/s) into the UCN range (0-7 m/s). Pulses of neutrons from a liquid hydrogen moderator at the ZING-P' spallation source at Argonne National Laboratory [3] arrive at a package of moving Thermica crystals (vertical velocity $\sim$200 m/s). Neutrons with a (vertical) velocity near 400 m/s then satisfy the Bragg condition and are reflected and Doppler shifted to form a cloud of very cold neutrons.

The crystals are mounted on the end of a rotor (radius = 120 cm) revolving in synchronism with ZING-P' pulses. The neutron beam is vertical, the rotor axis is horizontal, and, when the 400 m/s neutron pulses arrive, the crystal package is approximately 30° below horizontal and the neutron reflecting planes are horizontal. The scattering takes place at a Bragg angle of approximately 60° in the crystal coordinate system where a substantial range of neutron velocities ($\Delta V$) is reflected for a given spread of crystal angles ($\Delta\theta$). This arrangement avoids reflecting at a Bragg angle of 90° where reflections result in a minimal range of velocities ($\Delta V/\Delta\theta \sim 0$).

A detailed discussion of the scattering process has been given elsewhere [2]. In practice, the crystal package consists of a sandwich of Thermica sheets separated by aluminum wedges to broaden the angular spread and thus compensate for the rotation of the package during the pulse.

The velocity distribution of reflected neutrons was measured using a $^3$He counter placed 30 cm from the UCN production point with a polished nickel tube to guide the UCN toward the counter. The velocity component toward the detector was measured by time of flight and the results are shown in Fig. 1. The counter had a thin aluminum window which reflected neutrons with a longitudinal velocity component below 3.2 m/s. The counter efficiency was about 68% for neutrons with a velocity of 6.5 m/s. A Monte Carlo calculation produced the dashed curve in Fig. 1. The indicated errors refer to statistical uncertainties in the data. Although no normalization was ncessary, the agreement of the absolute values is somewhat fortuitous since the uncertainty in the aboslute values is estimated to be 20%. (In the future neutrons below 3.2 m/s will be detected by accelerating them by gravity.)

Fig. 1 shows only the longitudinal velocity component for the reflected neutrons. Taking into account the transverse components we estimate that 70% of the neutrons below 7 m/s in Fig. 1 are UCN. Correcting for the neutrons below the aluminum cutoff, counter efficiency, absorption in the counter window, and neutrons which miss the counter after being transmitted by the guide tube we estimate the flux transmitted by the guide tube is 5 UCN per pulse. The solid angle subtended at the crystal by the guide tube is 5 steradians. This yields a production rate at the crystal of 12 UCN/pulse. We estimate that the volume in front of the guide tube swept out by the crystal during the pulse of 400-m/s neutrons is about 100 $cm^3$. Hence the density in the production region is 0.12 UCN/$cm^3$.‡ Using the measured phase space density in the pulsed-neutron source, we find that our converter has an efficiency of 6% in the producing UCN from the available neutrons.

The pulsed-neutron source now under construction at Argonne, IPNS-I, is designed to provide a substantial increase in neutron flux. When this source becomes available in 1981 a high-precision search for the neutron electric dipole moment will be possible.

This work was supported in part by the U.S. Department of Energy. One of the authors (S.A.W.) wishes to acknowledge support in part by the Physics Division, NSF through Grant No. NSF-PHY 7608960, and another author (J.W.L.) through the Research Corporation and NSF Grant No. DMR-79-00908.

## Figure Captions

Fig. 1 The reflected neutron spectrum for the velocity component toward a counter placed at the end of a guide tube 30 cm from the crystal is shown. The velocities were determined by time of flight. The counter had an aluminum window which reflected neutrons below 3.2 m/s. The dashed curve is a Monte Carlo calculation which took into account the counter efficiency and the experimental arrangement.

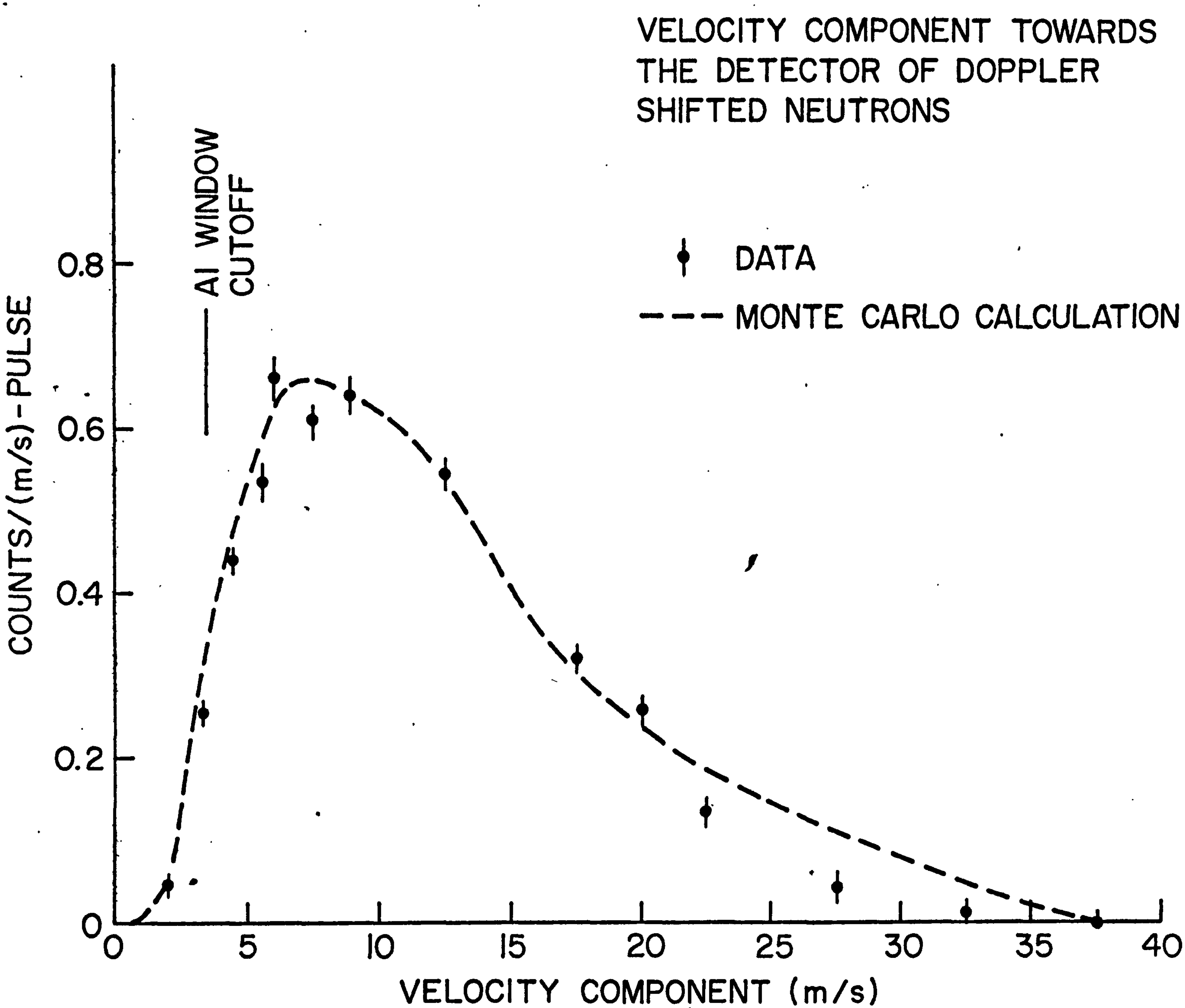
## References

[1]A.Steyerl, Springer Tracts on Modern Physics 80, 57 (1977).

[2]T. Dombeck et al., Nucl. Instr. and Methods (in press).

[3]J.M. Carpenter, Nucl. Instr. and Methods 145, 91 (1977); J.M. Carpenter, D.L. Price, and J.J. Swanson, IPNS: A National Facility for Condensed Matter Research, ANL-78-88, Argonne National Laboratory (1978).

‡To insure that the density of UCN stored in the bottle matches this peak UCN density a shutter is used. It is open during periods of peak UCN density but closed to prevent neutrons from escaping when the UCN density is low. The Argonne facility has a rotating shutter which performs this function.



VELOCITY COMPONENT TOWARDS THE DETECTOR OF DOPPLER SHIFTED NEUTRONS
DATA
MONTE CARLO CALCULATION
Al WINDOW CUTOFF
COUNTS/(m/s)-PULSE
0
0.2
0.4
0.6
0.8
0
5
10
15
20
25
30
35
40
VELOCITY COMPONENT (m/s)