ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ

Дубна

E13-96-210

A.Kirillov, L.Komolov, A.Kovalenko, E.Matyushevsky,
A.Nomofilov, P.Rukoyatkin*, V.Sharov, A.Starikov,
L.Strunov, A.Svetov

RELATIVISTIC POLARIZED NEUTRONS AT THE LABORATORY OF HIGH ENERGY PHYSICS, JINR

Submitted to «PANIC-96», May 22—28, 1996, USA

*E-mail: rukoyat@sunhe.jinr.dubna.su

1996

Deuterons provide the best way to generate neutron beams with well defined characteristics. The breakup cross section constitutes a significant ($\simeq 30\%$) part of the total (dA) cross section, which does not depend on energy. Also, the higher the energy of the produced beams, the better their properties: at high neutron velocities $v_n/c \gg k_{int}^{rms}/m_n$, the angular spread and yield at zero degree in the laboratory frame behave as $\sigma_{\theta_x} \sim 1/p_n$, $Y \sim {p_n}^2$, which means that the stripping neutron beam self-collimates as the energy rises. Starting from the chrestomathic experiment of Helmholz et al., neutron beams based on deuteron breakup were realized in different laboratories as soon as accelerated deuterons became available at their facilities[4]. Polarized neutron beams are obtained from vector polarized deuterons. The question of polarization of such beams is not so obvious *a priori*. In[5], the polarization transfer from deuterons to protons $\kappa = P_p/P_d$ at 0^o and $p_p = p_d/2$ at breakup were studied. It was shown that the predominant part of the secondary protons inherits the polarization of primary deuterons entirely, i.e. $\kappa \simeq 1$. As neutron beams are formed under the same conditions, one may assume that $P_n \simeq P_d$.

The neutron beam lines of the Laboratory of High Energy Physics operate on the basis of a slowly extracted deuteron beam from the Sychrophasotron. The maximum momentum of extracted beams is $9GeV/c$, the typical spill length - $0.5sec$. Acceleration cycles repeat each 8-10sec, depending on the energy. The nominal intensity of polarized deuterons at a maximum momentum is $10^9 ppc$ (up to $5 \cdot 10^{11} ppc$ can be extracted in the unpolarized mode). The deuteron polarization is oriented along the vertical axis and can be flipped each cycle, which is important from a methodical point of view. Its absolute value is measured by a specially dedicated fast polarimeter[6]. It was shown that there are no depolarizing resonances in the entire energy range of the Synchrophasotron. During recent operations, the average polarization of the deuteron beams was 0.535 ± 0.009[2]. We relate this value to our polarized neutron beams, also.

There are two neutron beam lines, both situated in the main experimental hall. The first was prepared at an early stage of the Delta-Sigma experiment working up and was used for methodical purposes. The channel was organized at the end of the VP-1[1] line where the slowly extracted beam dumps. The beam dump, whose central solid part was replaced by an insertion with a hole, served as the $3.5m$ long first section of the neutron collimator. It was followed by a $2.5m$ long iron block having a collimation hole $3cm$ in diameter. The distance from the neutron producing target to the collimator exit was $12m$, determining the solid angle $\simeq 5\mu sr$. At the certain bend angle of the sweeping magnet, it was possible to extract stripping protons from the same target into the 5V beam line where part of the flux was measured by a scintillator telescope. Using the measured value and the known relation between the acceptances for neutrons and protons, the flux in the neutron beam was calculated. The neutron intensity was also measured by activation of a CH–sample placed in the neutron beam. This is summary of the measurements (errors $\simeq 15-20\%$) carried out with a $20cm$ CH target-stripper are:

$P_n, GeV/c$	1.13	1.50	1.77	2.25	4.5
$I_n/I_d(10^9), ppc$	$7.6\cdot10^3/0.1$	$3.5\cdot10^4/0.3$	$7.7\cdot10^4/0.5$	$1.6\cdot10^5/0.8$	$1.0\cdot10^6/1.0$

The first four points are calculations from the proton fluxes and the last was taken from the activation measurements.

The spatial distribution in the neutron beam was checked by means of an assemblage consisting of three scintillators, S_A, S_1, S_2, a convertor ($10-30cm$ of polyethylene) and a multiwire proportional chamber, set up in the order: $S_A - Conv. - MWPC - S_1 - S_2$. "Neutral" logic $\bar{S}_A \cdot S_1 \cdot S_2$ triggered the proportional chamber, whereas "charged" $S_A \cdot S_1 \cdot S_2$ gave a charge contamination to the neutron beam. The neutrons interacted with the convertor matter and events with small angles, restricted by the S_2 counter ($\pm0.03r$), projected the neutron beam spot on the chamber planes. Event selection solely by this trigger was insufficient at neutron momenta $P_n \gtrsim 2GeV/c$ due to multiplicity growth, and an additional criteria, "only single events in the chamber planes", was then applied. The variances of measured and "true" distributions are connected via: $(\sigma_x^{(meas.)})^2 = (\sigma_x^{(beam)})^2 + L^2[(\sigma_{\theta_x}^{(beam)})^2 + (\sigma_{\theta_x}^{(sec.)})^2]$, where L is the distance from the convertor center to the chamber. In this way, it was obtained that $\sigma_x^{(meas.)} \cdot \sigma_y^{(meas.)} \simeq 11 \cdot 11mm^2$, where additions to the "pure" beam sizes does not exceed 10%. An example of the distribution, measured with a $22cm$ polyethylene convertor is shown in Fig.1a (no selection for multiplicity).

As the Delta-Sigma experiment required a large floor space in a beam zone, the existing 1V line was adopted for this purpose (see Figure). By means of the B1-B3 bending magnets, primary deuterons were bent from the host direction of the extracted beam (VP-1) at the f4 point and directed to a neutron producing target of $17cm$ $Be + 6cm$ C (T). The Q1,Q2 quadrupole dublet performed the required beam focusing. As it was important to retain the incident beam at strictly 0°, five multiwire ionization chambers were installed along the beam line, including at positions just before the target and at the beam dump (BD) exit. Also, the directions after each bending magnet were preliminarily traced by means of a thin

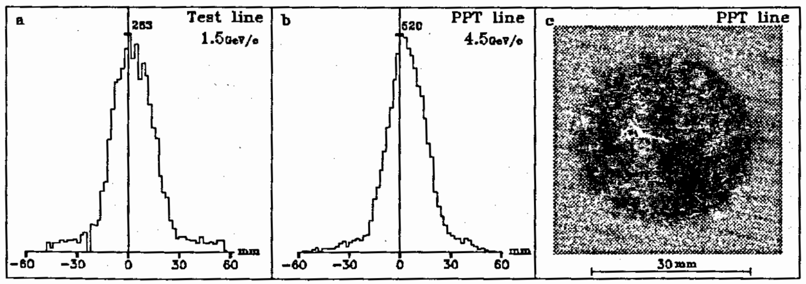
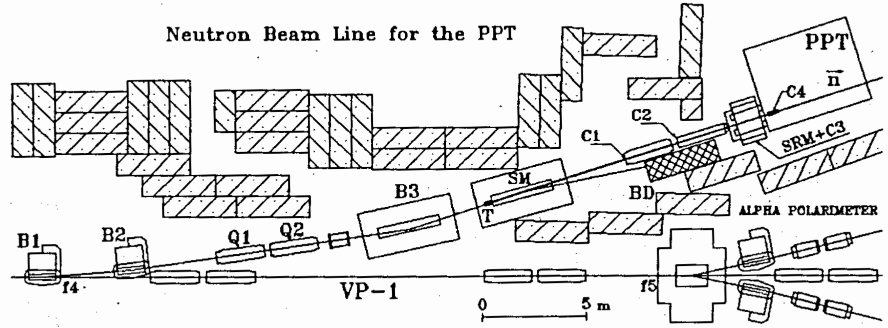


Figure 1: Neutron space distributions: a,b - from MWPC, c - exposed emulsion



current-carrying wire. To turn neutron spins from the vertical direction to a longitudinal one, the beam line was equipped with a magnet (SRM) of 2.7 *Teslameters* maximum field integral. The neutron beam was formed by a collimator composed of four stages: C1,C2 ($\oslash 4cm, \oslash 3cm$, iron) and C3,C4 ($\oslash 2.8cm$, brass) $6m$ in total length.The collimator defined $\Delta\Omega \simeq 3\mu sr$, a $1.2mrad$ angular divergence and a beam spot in the PPT, that fitted into a $\oslash 3cm$ circle. The neutron space distribution was continuously monitored during data taking runs using a MWPC placed $50cm$ downbeam from the PPT. A capsule with the target material, situated in a $2.6T$ longitudinal magnetic field, served as a convertor. The vertical distribution at $P_n = 4.5GeV/c$ is shown in Fig.1b (selection for multiplicity applied). A very visual test of the neutron spot was produced by an emulsion irradiated at the PPT entrance (Fig.1c). Neutron flux was measured by the setup detectors, calibrated using the activation method during a preliminary run. Date taking runs were carried out at 1.92, 3.31 and $4.50GeV/c$ neutron beam momenta. The intensities of the polarized neutrons, averaged over each run, were $2.7\cdot10^4$, $2.0\cdot10^5$ and $4.7\cdot10^5\vec{n}/cycle \pm 10-15\%$ at deuteron intensities on the target $3.0-6.5\cdot10^8\vec{d}/cycle$. Charge contamination was negligible. Momentum spread of the neutrons was 5% (FWHM).

This work was supported in part by the ISF and the Russian Government through Grant JHW 100, and by the Russian Foundation for Basic Research through Grants RFBR-93-02-16715, RFBR-96-02-18736a.

[1] I.Issinsky et al., Acta Physica Polonica, **B25**, 673 (1994)

[2] V.Sharov et al., In: Proc. VI Workshop on Spin Phenomena in High Ener. Phys., 1995, Protvino, to be publ.; Prep., DAPHIA/SPP 96-03, to be publ. in Z. Physik C v.71, N1, 1996;

[3] F.Lehar et al., Nucl. Instr.&Meth. **356**, 58 (1995)

[4] A.Helmholz, Phys. Rev. **72,** 1003 (1947); Yu.Kazarinov, et al., Zh. Eksp. Teor. Fiz. **43**, 35 (1962); G.Bizard et al., Nucl. Instr.&Meth. **111**, 451 (1973); Bevatron Exper. Handbook (1973); A.Gasparyan, JINR Comm., 1-9111 (1975); G.Korolev et al., Phys. Lett. **B165**, 262 (1985); H.Noumi et al., In: Proc. 9th Symp. on Acceler. Science, Tsukuba, p.205 (1993)

[5] E.Cheung et al., Phys. Lett. **B284**, 210 (1992); A.Nomofilov et al., Phys. Lett. **B325**, 327 (1994)

[6] V.Ableev et al., Nucl. Instr.&Meth. **A306**, 73 (1991)

Received by Publishing Department
on June 18, 1996.

Кириллов А. и др. E13-96-210
Релятивистские поляризованные нейтроны
в Лаборатории высоких энергий ОИЯИ

В Лаборатории высоких энергий ОИЯИ [1] на базе медленно выведенного пучка поляризованных дейтронов получены пучки квазимонохроматических поляризованных нейтронов с импульсами от 1,1 до 4,5 ГэВ/с. В зависимости от импульса интенсивность нейтронов изменялась от 10^4 до 10^6 частиц за цикл ускорения. В настоящее время пучки поляризованных нейтронов предназначены для проведения измерений разности полных сечений $(\vec{n}, \vec{p})$-взаимодействия (Дельта-сигма эксперимент [2]), проводимых с поляризованной протонной мишенью [3].

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна, 1996

Kirillov A. et al. E13-96-210
Relativistic Polarized Neutrons at the Laboratory
of High Energy Physics, JINR

Using slowly extracted polarized deuterons, available at the accelerator facility of the Laboratory of High Energy Physics JINR [1], polarized quasi-monochromatic neutrons with momenta from 1.1 to 4.5 GeV/c have been generated. Depending on momentum, from 10^4 to 10^6 polarized neutrons per accelerator cycle were produced. At present, the polarized neutrons are mainly intended for measuring the $(\vec{n}, \vec{p})$ total cross-section differences (the Delta-Sigma experiment [2]) with the Polarized Proton Target (PPT) [3].

The investigation has been performed at the Laboratory of High Energies, JINR.

Preprint of the Joint Institute for Nuclear Research. Dubna, 1996