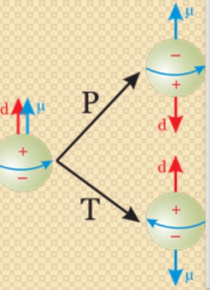
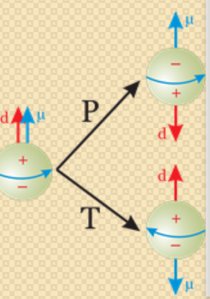
Scientific heritage of F. Shapiro: from the 20th century to the 21st century

V. Shvetsov



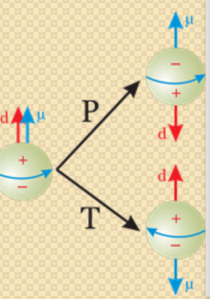
IN MEMORIAM OF F. L. SHAPIRO (April 6, 1915–January 30, 1973)

- Shapiro was born in Vitebsk on April 6, 1915;
- Graduated from school at 15 years of age and entered an electro technical school;
- Being only 19 years old, he proposed an original method for converting thermal energy into electric energy by changing the magnetic flux generated by controlled variations in the temperature of a ferromagnetic core near the Curie point;
- In1936, Shapiro entered the Faculty of Physics at Moscow State University. In 1941, he graduated with honors;
- In the same year, he joined the army as a volunteer and was seriously wounded;



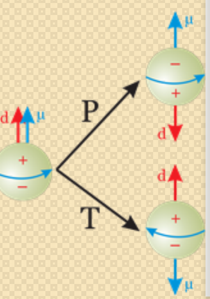
- After the war, Shapiro became a postgraduate student of I. M. Frank at the Institute of Physics (USSR Academy of Sciences, Moscow) and, from then on, remained a close associate of his teacher;
- After finishing his postgraduate studies, Shapiro – together with E.L. Feinberg, L.E. Lazarev, L.V. Groshev, and I.V. Shtranikh – embarked on investigations into subcritical uranium–graphite systems;
- In the early 1950s, Shapiro's group developed the method of neutron spectroscopy by the moderation time in lead. This spectrometer was used in an extensive series of experiments that studied neutron–nucleus interactions and which showed, among other things, that the cross section for neutron capture by nuclei can deviate from the 1/v law (an explanation of this phenomenon was also given in Shapiro's studies);
- Along with research work, Shapiro delivered lectures on neutron physics at the Faculty of Physics at Moscow State University (his students dubbed these lectures Shapiro's special course). His lectures were characterized by extreme clarity and precision of presentation; as a teacher, he was able to explain involved physics problems in very simple and

- In 1958, Shapiro became a deputy director of the Laboratory of Neutron Physics (headed by I. M. Frank) at the Joint Institute for Nuclear Research. In 1960, a pulsed fast-neutron reactor was commissioned at this laboratory, and Shapiro was among those who evolved the program of scientific investigations for this reactor;
- While continuing his studies in neutron physics, Shapiro took part in investigations of the Mössbauer effect. As a matter of fact, Shapiro became the pioneer of this new method of gamma spectroscopy in the Soviet Union. He developed the classical theory of the Mössbauer effect. Together with I.Ya. Barit and M.I. Podgoretsky, he indicated for the first time that, with the aid of the Mössbauer effect, an experiment aimed at testing the implications of the general theory of relativity could be implemented on the Earth. In the course of this experiment, it proved possible to observe the shift of the photon frequency in gravitational and inertial fields. For this, Shapiro proposed using narrow gamma lines as a source of photons. As a result, a velocity sweep of the 92-keV gamma-line resonance in the ^{67}Zn nucleus was obtained for the first time with a relative energy resolution of about 10^{-15}, which still remains a record value.



- In 1961, Shapiro indicated that slow neutrons from pulsed fast-neutron reactors could be employed in investigations into condensed-matter physics. He developed a highly sensitive method of inverse geometry. This method made it possible to study thermal vibrations of atoms in solid bodies and liquids and to measure self-diffusion coefficients in the critical state of liquid–vapor systems. Together with the Polish physicist B. Buras, Shapiro substantiated the application of the neutron-time-of-flight method to diffraction investigations. In addition, the method of neutron diffraction at magnetic structures in strong pulsed fields was implemented under his supervision;

- In April 1968, Shapiro proposed using Ultracold neutrons in a device for seeking the electric dipole moment of the neutron (such searches are of great importance for testing the conservation of T invariance). In the summer of the same year, a group of experimentalists headed by Shapiro observed for the first time ultracold neutrons (gas of elementary particles, neutrons) from IBR pulsed fast-neutron reactor installed at the Laboratory of Neutron Physics. After that, Shapiro initiated experiments with ultracold neutrons at more powerful stationary reactors at the Kurchatov Institute of Atomic Energy (Moscow), Research Institute for Atomic Reactors (Dmitrovgrad), and Institute of Nuclear Physics (Kazakh SSR Academy of Sciences, Alma-Ata);



Shapiro fell seriously ill in 1971 and passed away on January 30, 1973 three months before his 58th birthday

Ideas and Experiments Passed into the XXI Century

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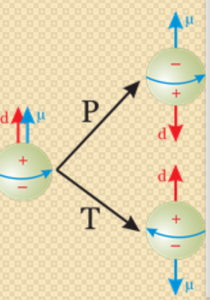
Neutron Spectroscopy

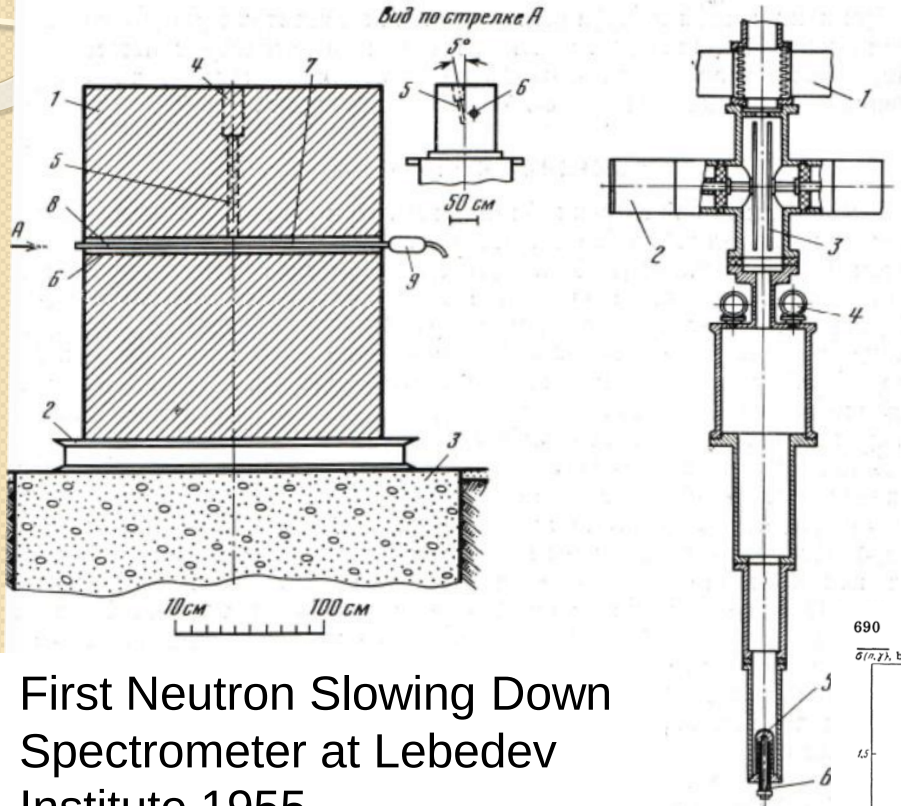
Ultracold Neutrons for EDM, Lifetime…

Neutron Scattering at Pulsed Sources

Neutron Spin Filter Based on DNP



Neutron Spectroscopy (Neutron Slowing Down Spectrometry)



First Neutron Slowing Down Spectrometer at Lebedev Institute 1955

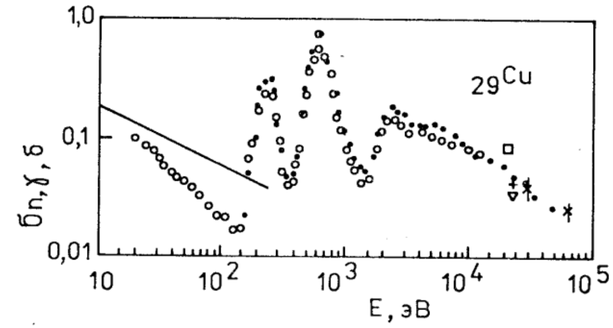


Рис.2. Энергетическая зависимость сечения радиационного захвата нейтронов ядрами меди: (•) и (○) — результаты измерений для образцов меди с эффективной толщиной $n = 3{,}2\cdot 10^{22}$ я/см^2 и $n = 6{,}5\cdot 10^{22}$ я/см^2 соответственно. В области энергий порядка десятков кэВ измеренные усредненные сечения хорошо согласуются с данными Гиббонса и др. [11] (×) и Шмитта и Кука [12] (+)

For A>>1 ξ≈2/A

$$t = A\lambda\left(\frac{1}{v} - \frac{1}{v_0}\right)$$

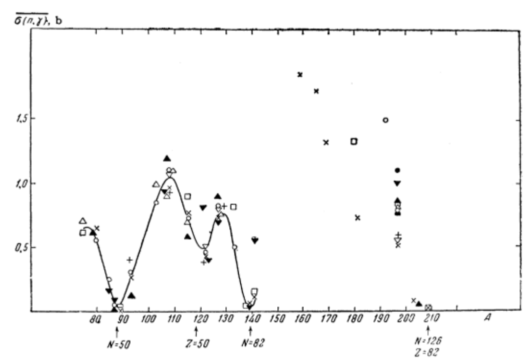
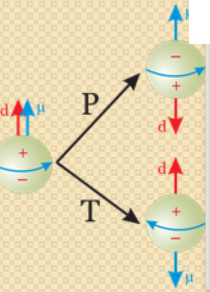
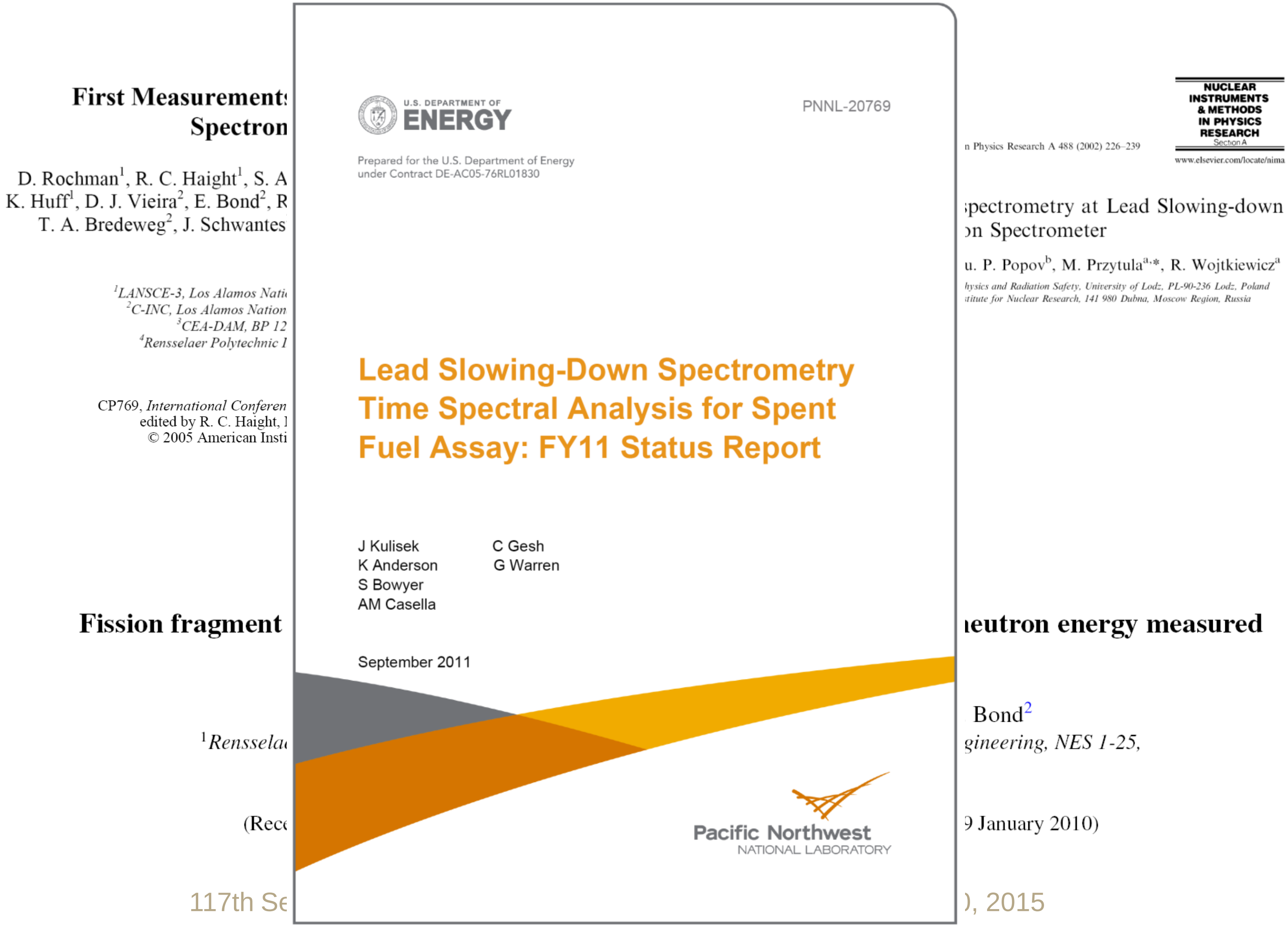


FIG. 10. Dependence of averaged radiative capture cross section of neutrons on mass number A of target nuclei, for odd Z (E = 30 keV); ○ – data obtained with the Pb slowing-down spectrometer, × – data of [1], △ – [3,4], ● – [6], ▼ – [23], ▽ – [27], □ – [28], + – [25], ▲ – [24,30], ■ – [36]. The results of measurements with an antimony-beryllium source (E = 24 keV), when extrapolated to E = 30 keV, gave a curve parallel to the measured curve. The point ○ for Rb^{87} is the upper limit of the cross section (~0.05 barn) obtained in our measurements.



Neutron Spectroscopy (Neutron Slowing Down Spectrometry)



First Measurement
Spectron

D. Rochman[1], R. C. Haight[1], S. A
K. Huff[1], D. J. Vieira[2], E. Bond[2], R
T. A. Bredeweg[2], J. Schwantes

[1]LANSCE-3, Los Alamos Nati
[2]C-INC, Los Alamos Nation
[3]CEA-DAM, BP 12
[4]Rensselaer Polytechnic I

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Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Lead Slowing-Down Spectrometry Time Spectral Analysis for Spent Fuel Assay: FY11 Status Report

J Kulisek
K Anderson
S Bowyer
AM Casella
C Gesh
G Warren

September 2011

Pacific Northwest
NATIONAL LABORATORY

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A

n Physics Research A 488 (2002) 226–239

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pectrometry at Lead Slowing-down
n Spectrometer

u. P. Popov[b], M. Przytula[a,*], R. Wojtkiewicz[a]

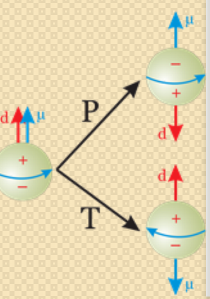
hysics and Radiation Safety, University of Lodz, PL-90-236 Lodz, Poland
titute for Nuclear Research, 141 980 Dubna, Moscow Region, Russia

Fission fragment
eutron energy measured

Bond[2]

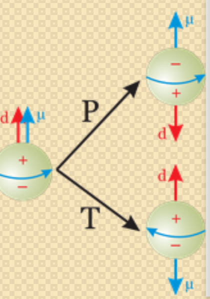
[1]*Rensselae*
gineering, NES 1-25,

(Rece
9 January 2010)



Neutron Spectroscopy at IBR

- Total and partial cross-sections;
- Measurements of the spins and magnetic moments of the compound nuclei;
- Development of the method for neutron polarization in energy range from eV to tens keV;
- Application of the pulsed neutron source for condensed matter studies, development of the “inverse geometry” method;



Neutron Spin Filter Based on DNP

Let’s consider unpolarized neutron beam as mixture of two completely polarized with intensities C_p^0 and C_a^0 and σ_a , σ_p corresponding cross-sections

If $\sigma_p \neq \sigma_a$ than after transition through polarized nuclear target beam becomes polarized

Nuclear polarization (I=1/2) $f_N = \frac{(n_+ - n_-)}{(n_+ + n_-)}$, n_+, n_- - number of nuclei

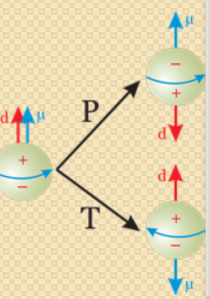
Neutron transmission through polarized target could be described with transmission coefficients: $T_p = \exp[-(n_+\sigma_p + n_-\sigma_a)]$, $T_a = \exp[-(n_-\sigma_p + n_+\sigma_a)]$

Having in mind definition of the polarization and fact that nuclear density in polarized target is $n = n_+ + n_-$, one can obtain an expression for neutron polarization:

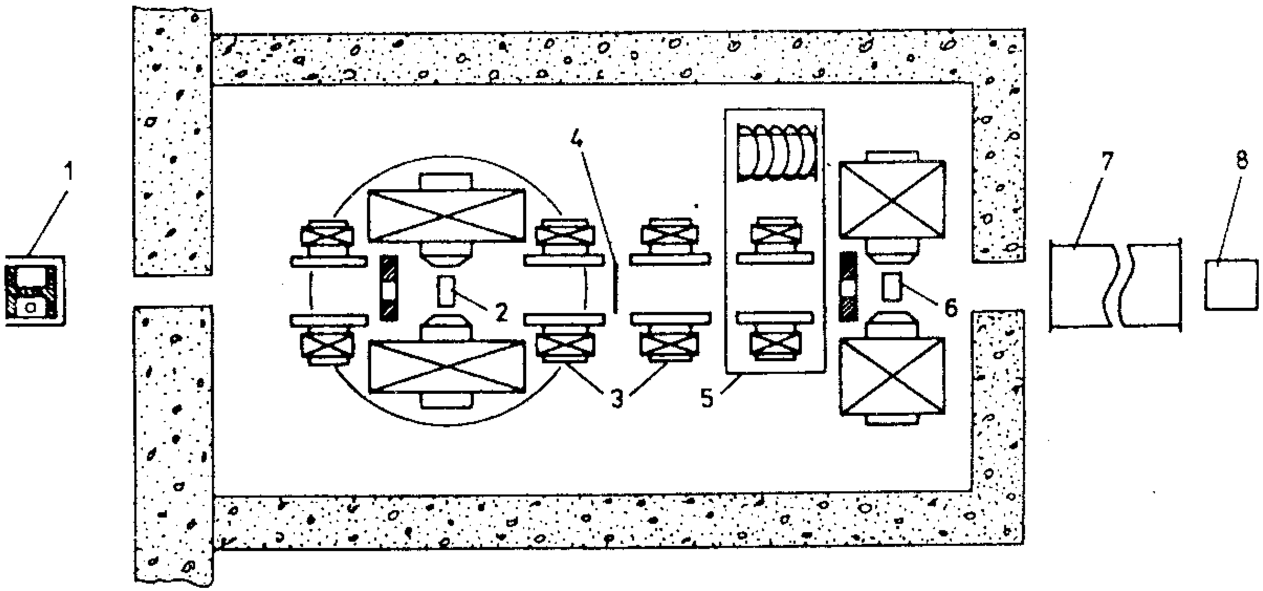
$f_n = -th\left(f_N n \frac{\sigma_p - \sigma_a}{2} \right)$, one can substitute $\frac{\sigma_p - \sigma_a}{2}$ with $\sigma_{pol} = \frac{I}{2I+1}(\sigma_+ - \sigma_-)$

here $\sigma_+ \_and\_ \sigma_-$ are cross-sections for $J = I \pm 1/2$ spin channels.

$\sigma_{pol}^{Hydrogen} = 16.7bn$



In 1961 Shapiro proposed construction of such polarizer and since 1964 experiments started



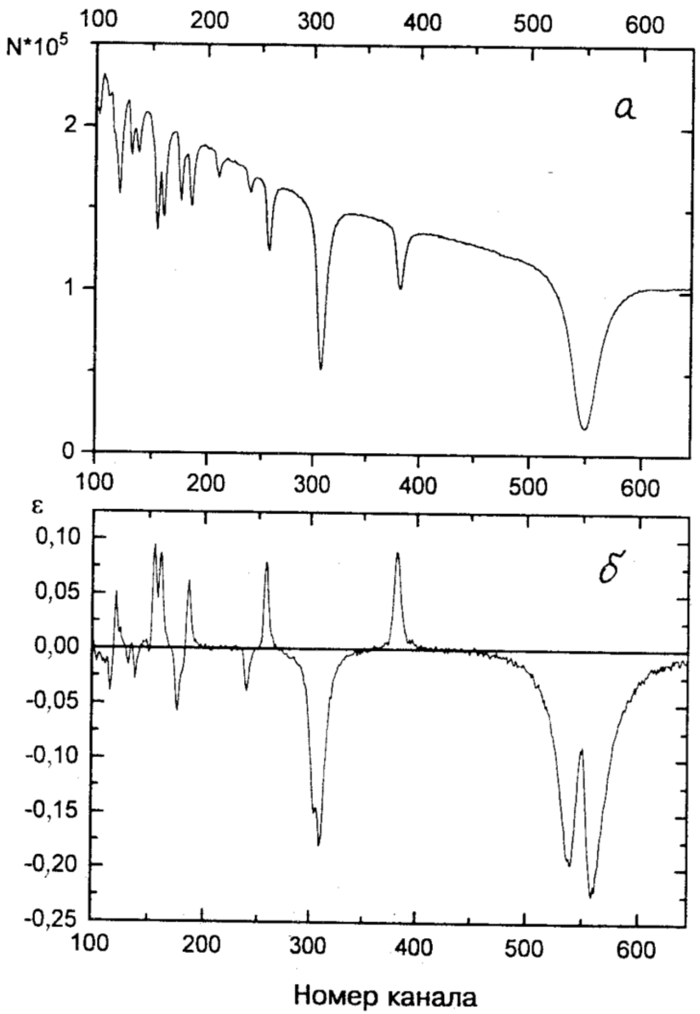
NEUTRON POLARIZATION BY TRANSMISSION THROUGH A POLARIZED PROTON TARGET

D. DRAGHICESCU, V. I. LUSHCHIKOV, V. G. NIKOLENKO, YU. V. TARAN and F. L. SHAPIRO
Joint Institute for Nuclear Research, Moscow

Received 4 September 1964

Volume 12, number 4 PHYSICS LETTERS 15 October 1964

^{165}Ho Resonances Spins Measurements – Spin Dependence of Neutron Strength Function



TOF spectra

Transmission effect

$$\varepsilon = \frac{N_p - N_a}{N_p + N_a}$$

Nuclear Instruments and Methods in Physics Research A 754 (2014) 10–14

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

Proton polarization above 70% by DNP using photo-excited triplet states, a first step towards a broadband neutron spin filter

T.R. Eichhorn [a,b], N. Niketic [a], B. van den Brandt [a], U. Filges [a], T. Panzner [a], E. Rantsiou [a], W.Th. Wenckebach [a], P. Hautle [a,*]

[a] *Laboratory for Developments and Methods (LDM), Paul Scherrer Institute, CH-5232 Villigen PSI, Switzerland*
[b] *Laboratory of Functional and Metabolic Imaging, École Polytechnique Fédérale de Lausanne (EPFL), CH-1015 Lausanne, Switzerland*

Shapiro and coworkers demonstrated that dynamically polarized proton spins offer an attractive possibility to realize a broad band neutron spin filter, as the spin-dependent neutron–proton cross-section is large in a broad wavelength range [8]. But so far an actual implementation of a polarized proton spin filter has been restricted to a few special cases [9–12]. This is most probably due to the necessary cryogenics and magnets needed for a classical DNP system.

[8] V.I. Lushchikov, Yu.V. Taran, F.L. Shapiro, Soviet Journal of Nuclear Physics 10 (1970) 669.

First Neutron Scattering Experiments at Pulsed Neutron Source

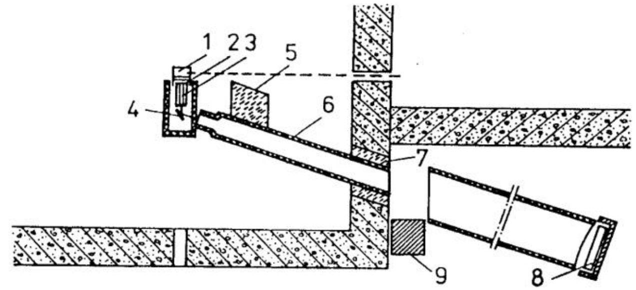


Рис.1. Схема установки для измерений с холодными нейтронами: *1* — активная зона реактора; *2* — замедлитель; *3* — бериллиевый фильтр; *4* — образец; *5* и *7* — защита; *6* — вакуумный нейтроновод; *8* — детектор; *9* — шибер

First experimental setup to study inelastic scattering of the cold neutrons on water samples with energy resolution one order of magnitude better than for existing at that time

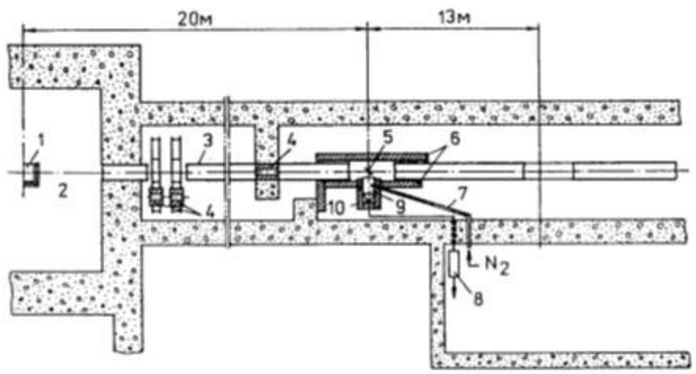


Рис.3. Схема установки для исследования жидкостей и твердых тел методом «обратной геометрии»: *1* — активная зона реактора; *2* — замедлитель; *3* — вакуумный нейтроновод; *4* — коллиматоры; *5* — образец; *6* — защита; *7* — азотопровод; *8* — электроника детектора; *9* — бериллиевый фильтр; *10* — детектор

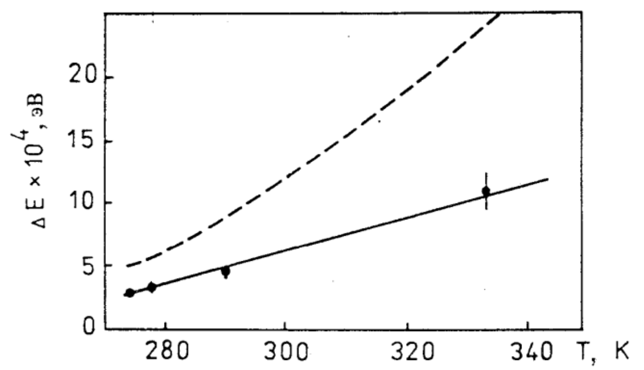
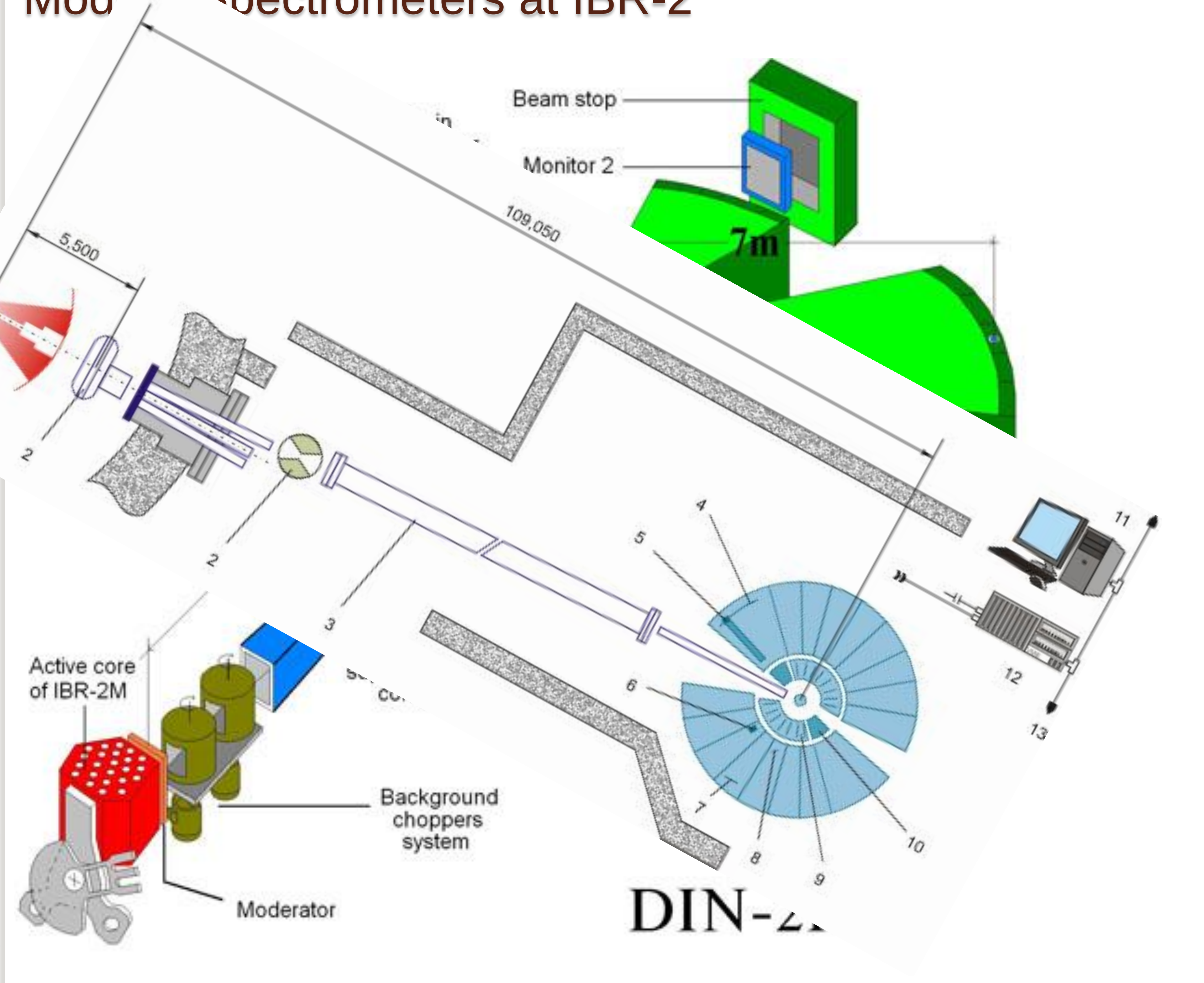
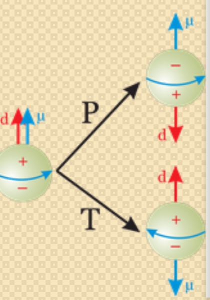


Рис.2. Температурная зависимость полуширины квазиупругого пика $\Gamma \equiv \Delta E$ для воды. Сплошная кривая — экспериментальные данные; штриховая — расчет по формуле непрерывной диффузии на основе экспериментальных значений *D*

Mod Spectrometers at IBR-2





UCN Discovery and Physics

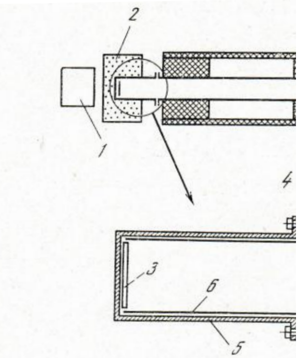
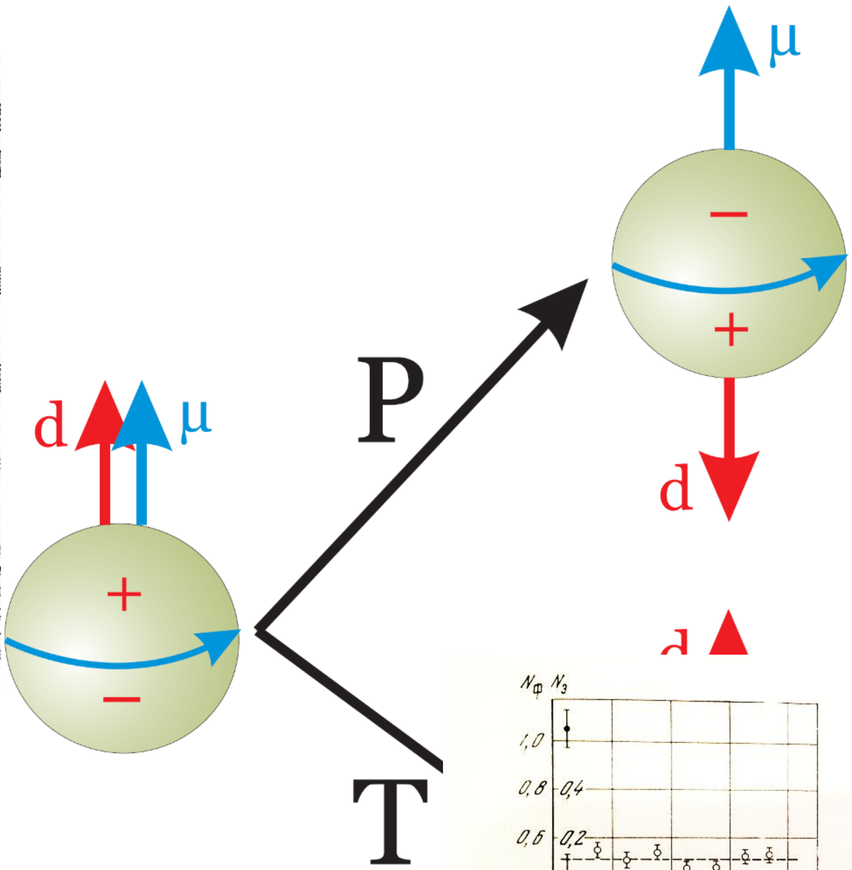


Рис. 131. Схема устан

1 — реактор ИБР; 2, 3 — замедли
ная труба с внутренним диаметро
из медной фольги; 7 — защита (п
актора; 9— защита детектора (пар
(ФЭУ-13 со слоями ZnS или ZnS
тектором <1 мм); 14 — механи



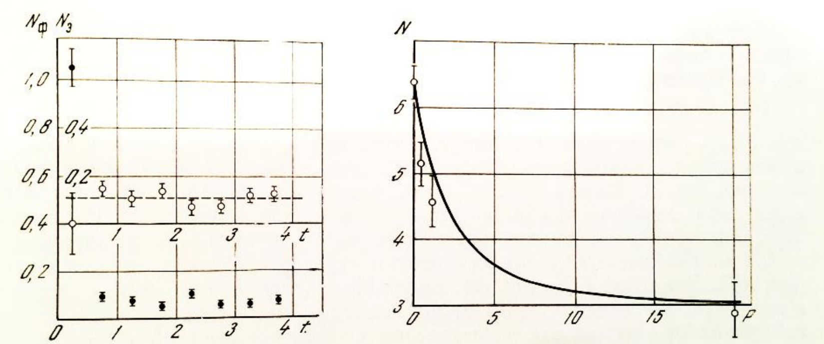
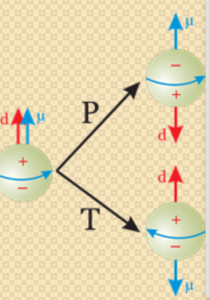


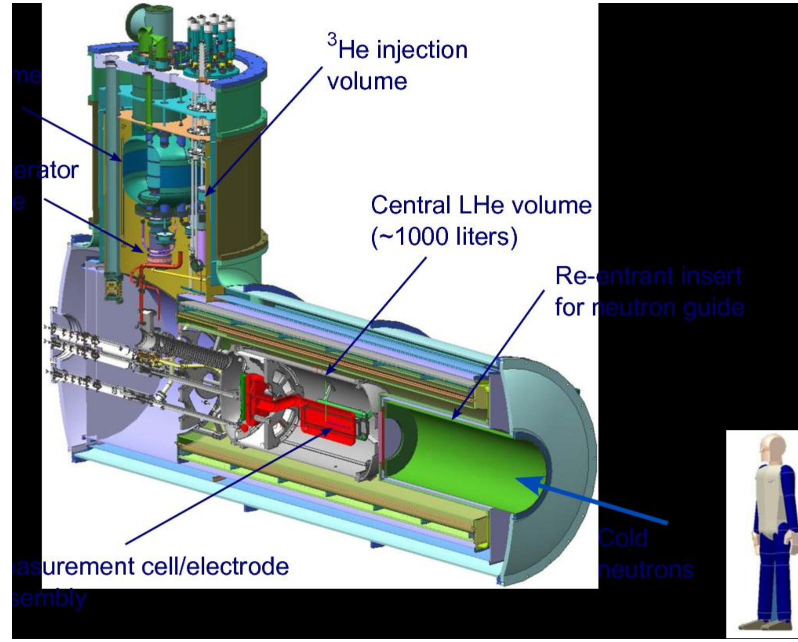
Рис. 132. Зависимость фона $N_ф$ (темные кружки) и эффекта $N_э$ (светлые кружки) — разности счетов без шторки и со шторкой от времени запаздывания t (*сек*) относительно вспышки реактора

По оси ординат отложено число отсчетов за 100 *сек*

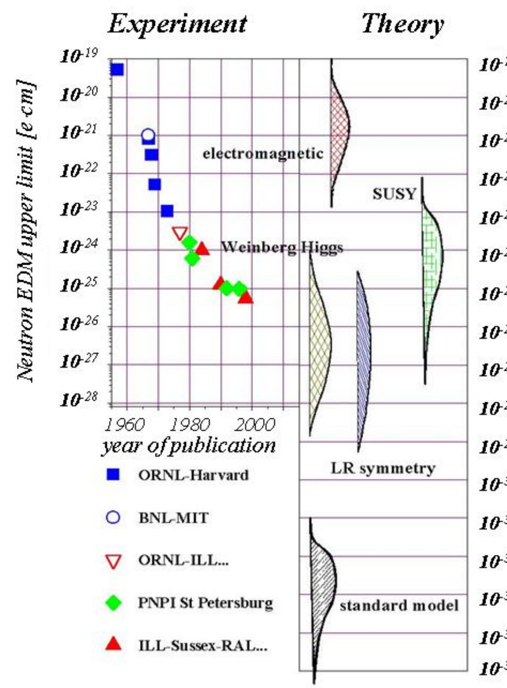
Рис. 133. Зависимость скорости счета ультрахолодных нейтронов N (отсчетов за 1000 *сек*) от давления гелия в трубе P (*мм рт. ст.*)

Теоретическая кривая нормирована к экспериментальному значению N при $P = 0$

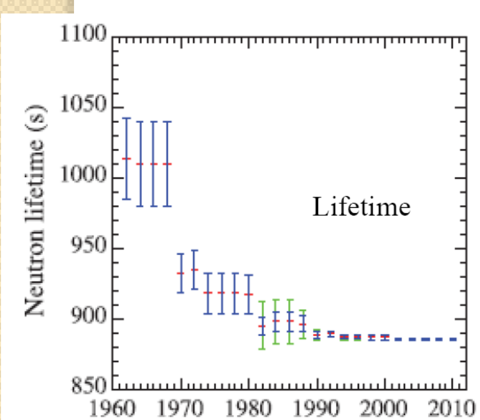




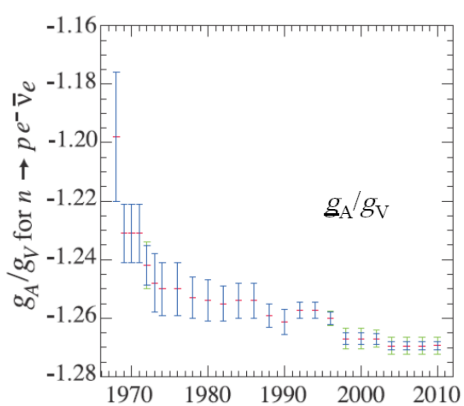
³He injection volume
Central LHe volume (~1000 liters)
Re-entrant insert for neutron guide



Experiment
Theory
Neutron EDM upper limit [e cm]
year of publication
electromagnetic
SUSY
Weinberg Higgs
LR symmetry
standard model
ORNL-Harvard
BNL-MIT
ORNL-ILL...
PNPI St Petersburg
ILL-Sussex-RAL...



Neutron lifetime (s)
Lifetime



g_A/g_V for $n \to p e^- \bar{\nu}_e$
g_A/g_V


XIX International Conference of
Young Scientists and Specialists
Dedicated to the 100-th Anniversary of
F.L. Shapiro
Dubna, 16-20 February 2015
AYSS-2015
December 20, 2014

International Seminar on Interaction of Neutrons with Nuclei

better late than never...

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NEWS

ISINN-23 (1-st circular)

Dubna, Russia, May 25 – 29, 2015

dedicated to the centenary of the birth of Fyodor L. Shapiro (1915 – 1973)

Registration is available HERE

Program profile

- Proposals of experiments for the PIK reactor;
- Fundamental properties of the neutron;
- Fundamental interactions & symmetries in neutron induced reactions;
- Properties of compound states, nuclear structure;
- Intermediate and fast neutron induced reactions;
- Gamma-decay of excited states;
- Nuclear fission;
- Neutron data for applied and scientific purposes;
- Methodical aspects;
- Physics of ultracold neutrons (UCN);
- Nuclear and related analytical techniques in the environmental and material sciences;
- ADS studies;

About

- The Frank Laboratory of Neutron Physics (FLNP) of the Joint Institute for Nuclear Research (JINR) in Dubna, Russia organize the International Seminar on Interaction of Neutrons with Nuclei: Neutron Spectroscopy, Nuclear Structure, Related Topics (ISINN). It's the traditional FLNP annual workshop in the field.
- The Seminar language is ENGLISH.