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NEUTRON-NEUTRON SCATTERING - POSSIBILITY OF IN-BEAM EXPERIMENT

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The problem of the direct measurement of the neutron-neutron scattering length remains open for many years /1/. No experimental attempt to solve it has been undertaken up to now. The experimental approach discussed many times and at different Labs is illustrated in Fig.1a.

Near or in the reactor zone (1) the through n-n scattering cavity channel (6) is installed to be viewed by the remote neutron detector (3) through the special collimator (5). This very important collimator secures the shielding of the detector from the neutrons born in the moderator.

In this approach one faces two main difficulties: design and building of a collimator with required characteristics /2/ and very strict vacuum requirements (10^{-11}-10^{-12} torr) to be met near the reactor radiation zone.

We suggest a different approach to the n-n scattering experiment: registration of n-n scattering events in a Maxwellian, collimated thermal neutron beam. Figure 1b schematically illustrates the approach. The thermal neutron beam from the reactor (1) passes through the collimator (5) and enters the vacuum tube. The n-n scattering events are registered with the cylindrical, position-sensitive detector (3). Because of the broad neutron spectrum the n-n collisions take place when faster neutrons catch up with slower ones. Let us estimate the collision density for three different cases.

1. A frozen neutron target having the density $\rho=\phi/v$, where ϕ is the thermal neutron flux, v the neutron velocity in the thermal beam. In this case the collision density is $N^{(o)}_{n-n} = \phi\rho\sigma_{n-n} = \phi^2\sigma/v$.

2. Colliding thermal neutron beams $N^{(+)}_{nn} = 2\phi^2\sigma/v$. The coefficient 2 stems from the doubling of the relative neutron flux for colliding beams.

3. One Maxwellian thermal neutron beam with the flux density

$$N(v)dv = A(\frac{2}{w^4})v^3 e^{-v^2/w^2} dv, \qquad (1)$$

where w is the most probable neutron velocity of the neutron density function. The collision density is

$$N_{nn}^{(\pm)} = (1/2)A^2(2/w^4)^2\sigma_{nn} \times$$
$$\times \int_0^\infty v_1^2 e^{-v_1^2/w^2} dv_1 \int_0^\infty |v_2 \pm v_1| v_2^2 e^{-v_2^2/w^2} dv_2 , \qquad (2)$$

where (+) stands for the colliding beams case, (−) for the one beam case, the coefficient (1/2) for the one beam case only, as in the integration every neutron is accounted twice. On transition to the polar coordinates the integration can be performed and it is easy to obtain that $N_{nn}^{(-)} / N_{nn}^{(+)} \cong 1/8$.

This means that the collision density in the Maxwellian beam is

$$N_{nn}^{(-)} \cong \phi^2\sigma_{nn}/4v \quad . \qquad (3)$$

The n-n scattering in the beam will with great probability knock the participating neutrons out of the beam and thus allow their being detected. Let us estimate the n-n scattering rate for the following experimental conditions: the neutron flux in the bottom of the reactor channel $\phi_0 = 10^{15}$ cm^{-2}s^{-1}2π sterad , the diameter of the beam d = 10 cm (s = 80 cm^2), $L_1 + L_2$ = 4 m, L = 2 m, σ_{nn} = 36 b (f_{nn} = 17 fm), w = 2.5 × 10^{5}cm s^{-1}. In this case the flux density in

the middle point of the detector tube is

$$\phi = \phi s/2\pi(L_1 + L_2 + L/2)^2 = 5 \times 10^{10} \text{ cm}^{-2}\text{s}^{-1}$$

and

$$N_{nn} = 7.2 \times 10^{-7} \text{ cm}^{-3}\text{s}^{-1}.$$

In the internal volume of the detector, V = SL = 1.6 ×10^4 cm^3, we have N_{nn} ≅ 5 events/hour. It is necessary to measure the coordinates (ϕ,z) and the time of registration for both neutrons. We performed the Monte-Carlo simulation of the experiment under assumption that the detector was a very thin wall cylinder with the diameter of 20 cm and the beam divergence was neglected. In Fig. 2 the registration efficiency of the scattered neutrons is shown as a function of the z-coordinate of the point the scattering event occured in. Figures 3 and 4 show the distribution of the differences in registration times and z-coordinates of the scattered neutrons, respectively.

It is our belief that, in spite of the low counting rate, the reported approach has some advantages. First, it does not require building of a through cavity channel in the reactor zone. Just the usual thermal neutron guide tube can be used for the experiment. Second, the vacuum requirements are much less strict in this case. For example, in order to have the accidental coincidences background due to the scattered on residual gas neutrons of about 10% of the effect (within the FWHM limit of Δt and Δz distributions), it suffices to maintain the vacuum in the collision chamber of about 10^{-8} torr, while in the conventional approach to have the same background to effect ratio it is necessary to maintain the vacuum of of about 2×10^{-11} torr. Moreover, in our approach there is no necessity in creating vacuum near the active zone of the reactor. It should be noted also, that within the earlier suggested approach, it is extremely difficult to determine with high precision the neutron momentum (three components) - coordinate - time (for the pulsed mode of reactor operation) distributions in the region of the neutron-neutron scattering. It appears much easier to solve this problem within the approach we suggest.

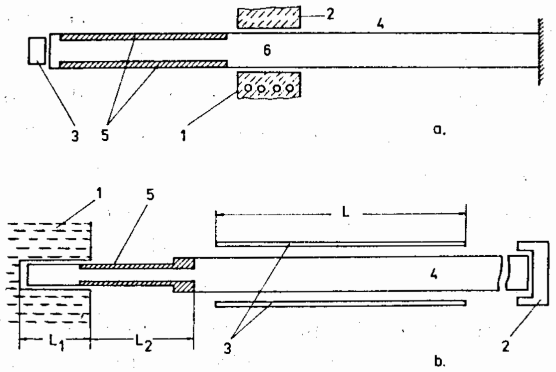

Fig.1. Experimental n-n scattering schemes.

a) Conventional approach.

1. active reactor zone and moderator,
2. neutron moderator-reflector,
3. neutron detector,
4. vacuum volume,
5. special collimator,
6. high vacuum n-n scattering cavity.

b) This approach.

1. active reactor zone and moderator,
2. neutron trap,
3. cylindrical, position-sensitive neutron detector,
4. vacuum volume,
5. special collimator.

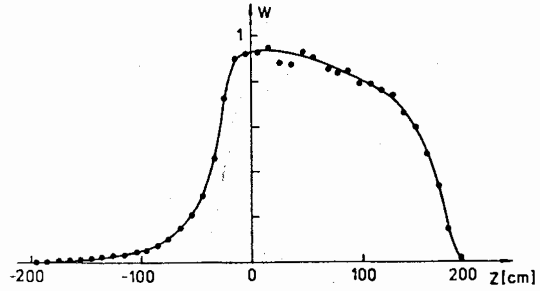

Fig.2. The registration efficiency of the two neutrons participating in the n-n scattering as a function of the z-coordinate of the n-n collision site in the experimental geometry described in the text.

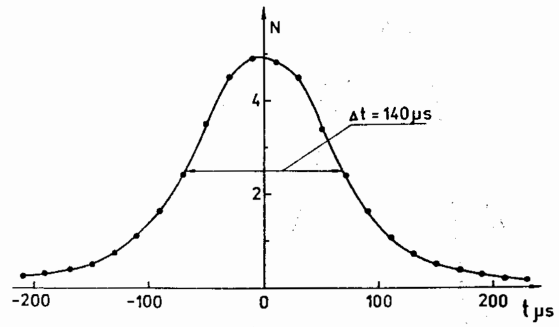

Fig.3. The distribution of differences in registration times of the scattered neutrons.

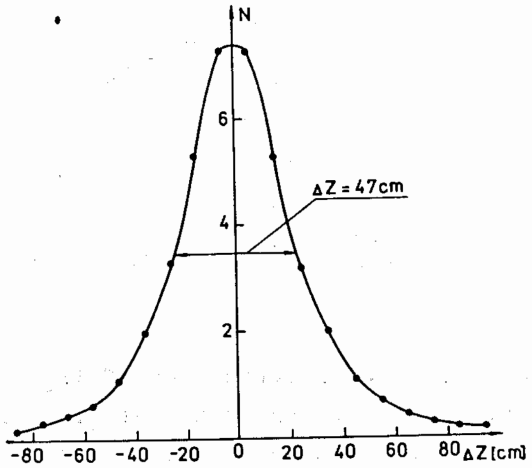

Fig.4. The distribution of differences in z-coordinates of registration of the scattered neutrons.

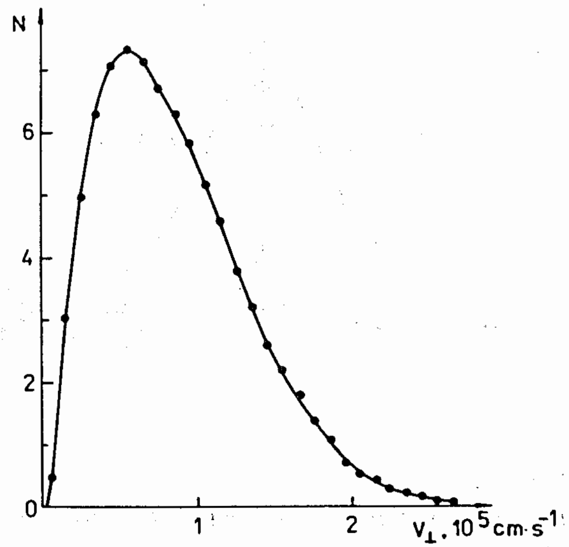

Fig.5. The distribution of the normal to cylindrical detector surface component of the scattered neutrons velocity.

Finaly, there are several criteria based on the space-time correlation of the registered events, which allow the effect from background separation. The most important part of the proposed experimental arrangement - the collimator for the formation of the neutron beam - is not discussed in this paper. The requirements to this collimator are the same as in the conventional approach to the n-n scattering experiment.

References

1. V.D.Ananjev et al. Preprint JINR, 13-4392, Dubna, 1969 (in Russian);
   W.C.Dickinson, E.M.Lent, C.D.Bowman, Report No.UCRL-50848, Berkeley (1970);
   R.Dobrozemsky. Nucl.Instr.Meth., 1974, 118, p.1;
   M.V.Kazarnovsky et al. Proc.Int. Seminar on Intermediate Energy Phys., v.I, Moscow, 1990, p.219.
2. L.V.Spencer,S.Woolf, Nucl.Instr.Meth., 1971, 97,567.

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