EXPERIMENTAL IMPROVEMENT OF NEUTRON ELECTRIC CHARGE ESTIMATION

Yu. Alexandrov
FLNP, JINR, Dubna

Abstract

The combination of two well-known crystalline diffraction methods described by Shull earlier (1967, 1986) was analysed to improve the upper experimental limit of neutron electric charge.

I would like to tell you about new proposition of experimental improvement of neutron electric charge.

The neutron is conditionally assumed to be neutral but it is not theoretically forbidden for it to have a small electric charge. Now the upper limit of neutron electric charge is $(0.6 \pm 1.1)x10^{-21}$ electron charge (ILL, 1987 [1]). It was obtained on the complicated enough installation. I will you show that more precise corresponding experiment is possible by the combination of two well-known crystalline diffraction methods described by Shull et al. earlier (1967, 1986).

The first method (Shull et al., 1967, [2]) employed very high angular sensitivity of a double-crystal silicon spectrometer which is shown in Fig.1.

It shows the positions of the crystals A and B with identical reflecting planes (hkl) parallel to the face of he crystal. The crystal A is in parallel position to crystal B. A white beam of neutrons is introduced on the crystal A. A Bragg reflection beam from crystal A is incident on crystal B at the same angle and is than reflected by the latter. During the rocking, the crystal B satisfies the Bragg condition simultaneity over the full wavelength range. As a result a sharp fall in the intensity is observed. A typical rocking curve obtained by Shull is shown in next Fig.2. In Shull's experiment the crystal A was irradiated by white spectrum of neutrons from reactor. The crystals A and B were set for a (111) Bragg reflection from each crystal corresponding to a mean neutron wavelength of 2.4 Å. If L is the length of the neutron path in a homogeneous electric field E generated between two parallel plates than a neutron ray will be deflected by an angle β given by the formula:

$$\beta = \frac{Q_n EL}{mv^2} \qquad (1)$$

where m is the neutron mass and v is its velocity.

In Shull experiment with the values of E = 225 000 V/cm, L = 150 cm, v = 1650 m/sec (λ = 2.4 Å), β was equaled to be $1.4x10^{-3}$ sec of arc if neutron electric charge was to be $5.6x10^{-18}$ electron charge. The experiment was performed at MIT (USA). The reactor power level was evaluated from 2 to 5 MW.

The second experiment (Finkelstein, Shull and Zeilinger, 1986, [3]) was based on the effective mass concept predicted by the dynamical diffraction theory. I will not explain this concept in details. I can you give the corresponding references [4,5]. In perfect crystals the effective inertial mass of the diffracting neutron is many times smaller than normal. In the presence of external force P the neutron trajectory must exhibit a deflection many times larger than normal. The Newton's second low is

$$a = \frac{P}{m} \pm \frac{P}{m}(1-\Gamma^2)^{3/2}\frac{\Delta_0}{d_{(hkl)}} \qquad (2)$$

where $\Delta_o \sim \frac{\cos\theta_B}{\lambda F}$ is the pendellosung length (part of mm), F is the structure factor, $\Gamma = \tan\Omega / \tan\theta_B$. Ω is the angle between the neutron propagation direction and (hkl) planes, θ_B is the Bragg angle.

For neutrons propagating along the lattice planes $\Gamma = 0$ (because $\Omega = 0$) and effective mass $m^{\otimes} = m \frac{d_{(hkl)}}{\Delta_0}$. For the Si(220) reflection and $\lambda = 3\text{Å}$, $m^{\otimes}/m = 4.28\text{x}10^{-6}$ and deflection of neutron beam will be proportional to $1/m^{\otimes}$ that is to say by the order of 10^5 times larger than normal. The «±» sign indicates that the neutron can have either positive or negative mass.

According to aforecited formula (1) β will be equaled to $3.5\text{x}10^{-3}$ sec of arc at $Q = 1.7\text{x}10^{-21}$ e , E =50 000 V/cm, L=15 cm, and v = 1300 m/sec (λ =3Å).

The top of view of Shull's experimental arrangement (MIT, USA) for magnetic charge estimation is shown in next Fig.3 [3]. Two connected silicon crystals are used in this experiment.

If the neutron has an electric charge, the application of an electric field instead of magnetic one will deflect a neutron ray. Using the MIT method one can improve neutron electric charge estimation up to several unit of times making use of MIT reactor even.

Combining together the Shull methods and using the PSI, new ISIS, Los Alamos installations, the ILL or new Garching FRM-II reactors, one can improve the neutron electric charge estimation up to several tens of times (or more). The result depend from a source of neutrons which was elected.

References

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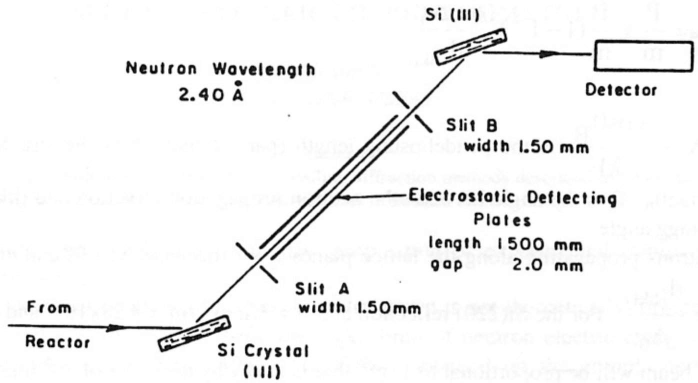

FIG. 1. Schematic diagram of double-crystal spectrometer and electrostatic-deflection system which has been used in the search for a neutron charge.

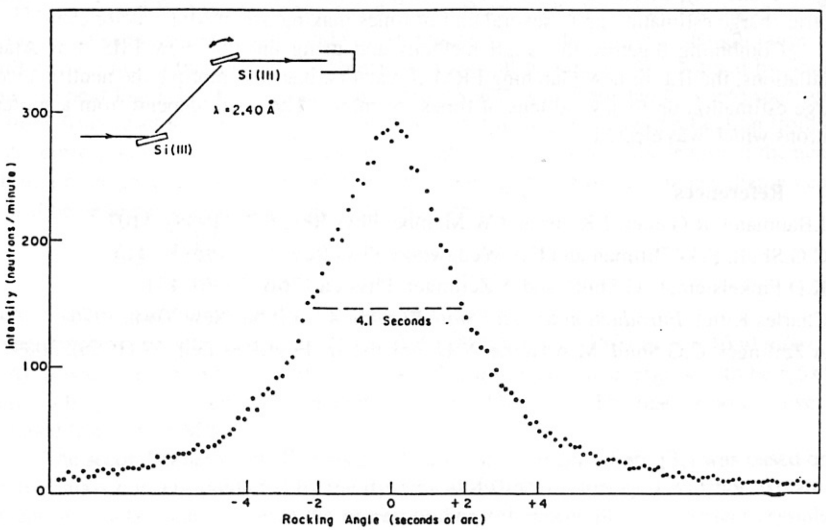

FIG. 2. Typical rocking curve if intensity versus angular orientation of second crystal in double-crystal spectrometer.

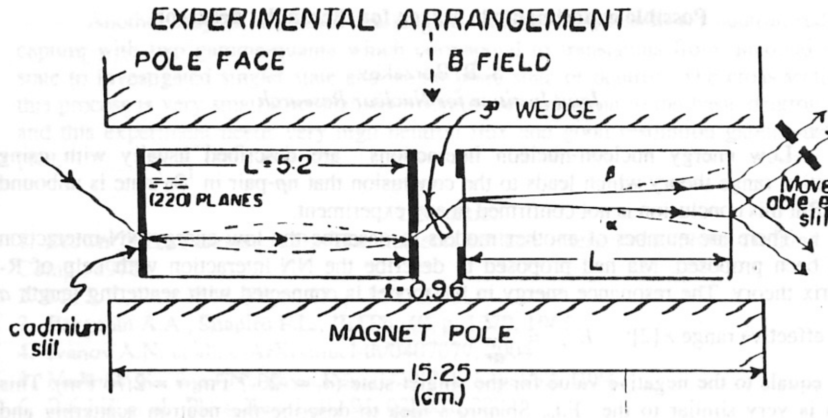

Fig.3. Top view of the MIT (USA) experiment. The dashed lines illustrate the effect of a force on the neutron trajectories inside the crystal