NEW MEASUREMENT OF ELECTRIC DIPOLE MOMENT OF NEUTRON

I.S.Altarev, Yu.V.Borisov, N.V.Borovikova, S.N.Ivanov, E.A.Kolomensky, M.S.Lasakov. V.M.Lobashev*, V.A.Nazarenko,A.N.Pirozhkov, A.P.Serebrov, Yu.V.Sobolev, E.V.Shulgina, A.I.Yegorov

* Institute for Nuclear Researches, Moscow

A search for the electric dipole moment (EDM) of the neutron remains one of the most important experiments in the problem of CP-violation. A nonzero value of EDM could manifest some new physics beyond Standard model, an improvement of the upper limit helps to eliminate a number of theories of CP-violation.

Essential features of the recent set-up were as well as in [1,2] a use of two 20 liter volume chambers for UCN storage and of a system for simultaneous detecting UCN polarized in two opposite directions. Thereby we have four independent measurements for each cycle of neutron storage with signs of EDM opposite by pairs. It allowed to cancel fluctuations of common magnetic field and of oscillating field frequency, intensity fluctuations of nonstatistical origin and common part of pick-up from high voltage on the electrical circuits in the first order. The semiartistic sketch of the set-up internal part is shown in fig.1.

The storage chambers are formed by three lids, separated by insulating quartz rings. The internal lid common for the both chambers, is connected to high voltage input and produces opposite-directed electric fields in the both chambers. The upper and lower lids are grounded and connected with each other by thin arches, so that the central electrode is embraced by grounded envelope. The storage chamber lids are made of aluminum sputtered with beryllium and quartz rings of 10 *cm* height are covered with BeO. Storage time 70—100 seconds was used as optimal with respect to sensitivity to EDM. The four layer permalloy magnetic shield was used. Magnetic field intensity was 18 *mG*, implying resonance frequency *55 Hz*. Frequency of oscillating field for neutrons was prepared by direct rescaling frequency of self-generating Cs optically pumped magnetometer. The use of frequency mixer allowed to average the frequencies of two or three magnetometers (the third magnetometer was placed aside the storage chambers) that improved a stabilization of the resonance. In accordance with stabilization mode we combined the data in groups of one-channel or two- or three-channel stabilization.

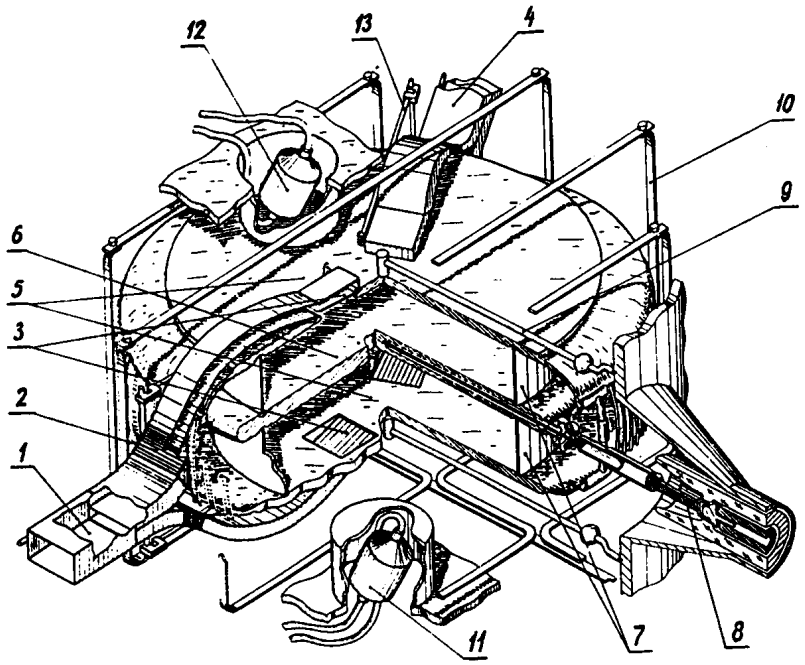

Fig.1. Internal part of EDM set-up. Permalloy shield, vacuum chamber, neutron polarizer and detection system are not shown: *1* — input UCN guide; *2* — insulating section of neutron guide; *3* — entrance shutters; *4* — output UCN guide; *5* — upper and lower lids of neutron storage chambers; *6* — central high voltage electrode; *7* -quartz insulating ring, *8* — vacuum high voltage input. *9* — qrounding bar of upper lid; *10* — part of oscillating field coil; *11*— lower Cs optically pumped magnetometer; *12* — upper magnetometer; *13* — shaft for shutter operation

Procedure of the measurement included filling the chambers with polarized UCN (30-40 *s*), confinement (70—100*s*) and discharge and counting (40 *s*). 2 seconds long oscillating field pulses were applied at the beginning (after 0.5 seconds of storage) and at the end of confinement time. The polarity of the electric field

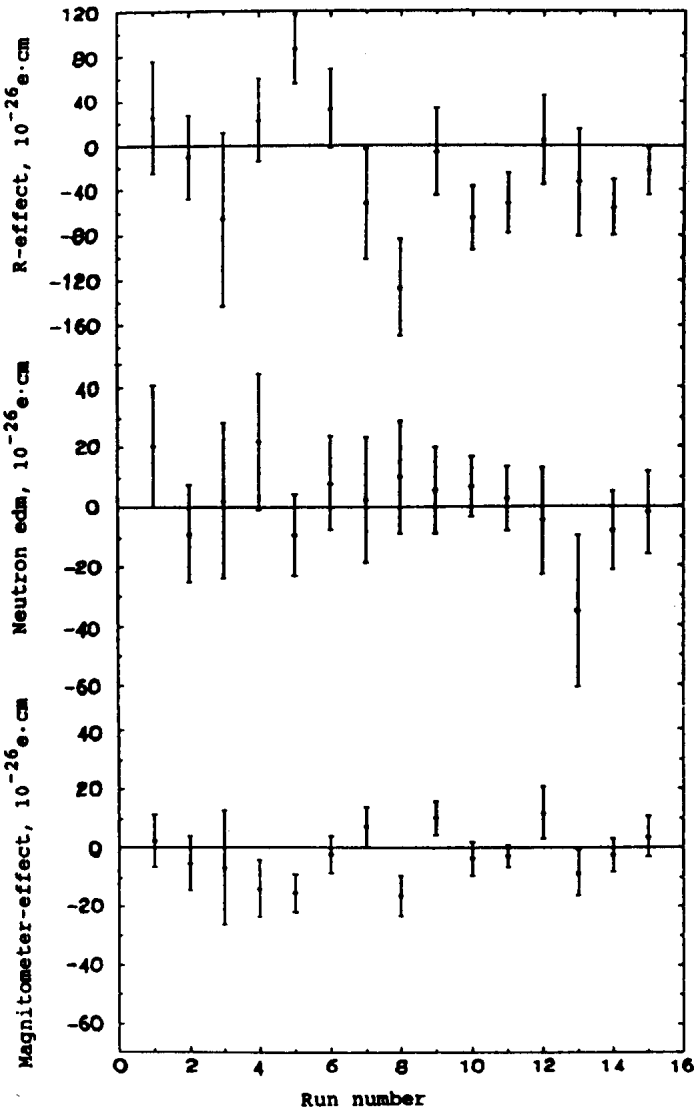

Fig.2. Results of measurements for runs. Neutron effects are applied without any corrrection. MNL is corrected by linear regression and recalculated to the neutron system in accordance with distance between magnetometers

was reversed in 40 seconds interval between storage cycles. The phase shift of oscillating field between the first and second pulses ($\pm 90^0$) was changed after 4 cycles. A very small shift of neutron resonance frequency was periodically (after 2 cycles with opposite electric field) inserted to measure the slope of resonance curve. The sequence of electric field reversal, frequency shift and phase change were chosen so as to compensate the smooth drift of resonance conditions. Each run of the measurement coincided with a period of reactor operation (10—12 days). Condition of the measurement, including intensity of UCN, high voltage level (120—150 *kV*) during the run were usually identical. We had 15 runs comprising 13863 cycles at average intensity of electric field ± 14.4 *kv/cm*. The magnetic field strength was controlled by Cs magnetometer during neutron precession time. The data of runs for d_n and false effects R false are given in fig.2. False effect because of influence of magnetic field was calculated as $R = 1/2\,(d^U - d^L)$.

The final result for EDM was obtained using r.m.s. error of each series for the calculation of its weight. The r.m.s. error and the statistical one for the final result amounts $4.0 \cdot 10^{-26}\ e \cdot cm$ and $3.9 \cdot 10^{-26}\ e \cdot cm$ correspondingly. The difference between them never exceeded 10% over all the series.

The overall result for EDM is:

$$d_n = +(0.7 \pm 4.0) \cdot 10^{-26}\ e \cdot cm.$$

Magnetometer readings may be used to measure inhomogeneous magnetic pick-ups, imitating EDM in a two-chamber system. The neutron chambers are disposed closely, the distance between their centers being 12 *cm*, which is small compared with the distance between the magnetometers — 45 *cm*. So taking into consideration the fact that value of $d_n = 1/2\,(d^U + d^L)$, the effect on magnetometers being recalculated to the neutron frequency is 7.5 times more sensitive to vertical gradient of the magnetic field than false EDM, measured by the neutron system. The magnitude of the magnetometer effect was corrected by a linear regression procedure taking into account values of R for the two-channel mode and both R and lower magnetometer data for the one-channel stabilization mode. The data of runs for magnetometer effects are given in fig.2. Recalculating the frequency shift to EDM units we obtain $d_n = -(1.9 \pm 1.6) \cdot 10^{-26}\ e \cdot cm$, coming from inhomogeneous magnetic pick-ups of various origin. No noticeable correlation between d_n and average leakage currents during the cycle was found. Other corrections were found to be negligible. The result of the experiment therefore has to be corrected only for the magnetometer value obtained by regression procedure. The r.m.s. or statistical error has to be accomplished by the error of magnetometer effect, which may be considered as the main systematical error. So we obtain:

$$d_n = +[2.6 \pm 4.0(\text{stat.}) \pm 1.6(\text{syst.})] \cdot 10^{-26}\ e \cdot cm.$$

The upper limit, which can be derived from the recent result according to a tradition may be written for 95% confidence limit as: $|d_n| < 11 \cdot 10^{-26}\ e \cdot cm$. This limit appears to be somewhat more conservative than the limit given by ILL group $|d_n| < 12 \cdot 10^{-26}\ e \cdot cm$ [3,4] owing to absence of any additional spread of the data besides statistical one in our measurements and better control of possible systematical biases.

References

1. Altarev I.S. et al. //Phys. Lett. 1981. V.102B. P.269;
Lobashev V.M., Serebrov A.P. //J. Phys., 1984. V.45. P.3.
2. Altarev I.S. et al. // JETP Lett., 1986. V.44. P.460.
3. Pendlebury J.M. et.al. //Phys.Lett., 1984. V.136B.P.327.
4. Smith K.F. et al. //Phys. Lett., 1990. V.234B. P.191.