MEASUREMENT OF NEUTRON ELECTRIC CHARGE BY THE SPIN INTERFEROMETRY TECHNIQUE

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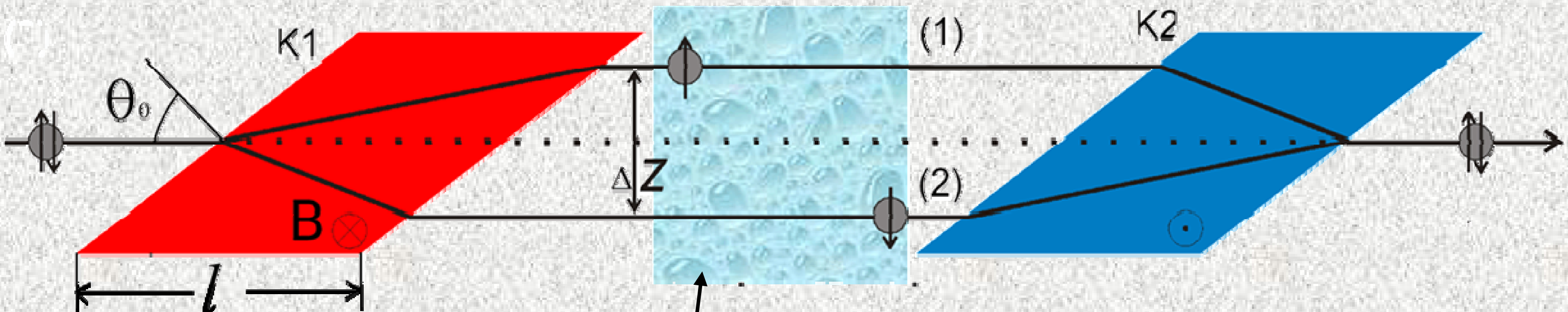
Idea of SESANS technique



$$\psi_i = \frac{1}{\sqrt{2}}\begin{pmatrix}\frac{-i\varphi_0}{2} \\ \frac{i\varphi_0}{2}\end{pmatrix}$$

Vsr (z)

$$\psi_{out} = \frac{1}{\sqrt{2}}\begin{pmatrix}\frac{-i\varphi_{sr}}{2} \\ \frac{i\varphi_{sr}}{2}\end{pmatrix}$$

$$\varphi_{sr} = (Vsr(z) - Vsr(z+\Delta z))/\hbar\cdot\tau$$

Let's φ_0=0, then $$P_{out} = \frac{\langle \psi_{out} | \sigma | \psi_{out} \rangle}{\langle \psi_{out} | \psi_{out} \rangle},$$

where σ – Pauli matrices.

As a result we have

$P_x = \cos \varphi_{sr}$;

$P_y = \sin \varphi_{sr}$;

$P_z = 0$.

SESANS setup at TU Delft

http://tnw.tudelft.nl/index.php?id=33186&L=1

Neutron charge experiment

J.Baumann, R.Gahler, J.Kalus, W.Mampe, PR D37, 3107 (1988)

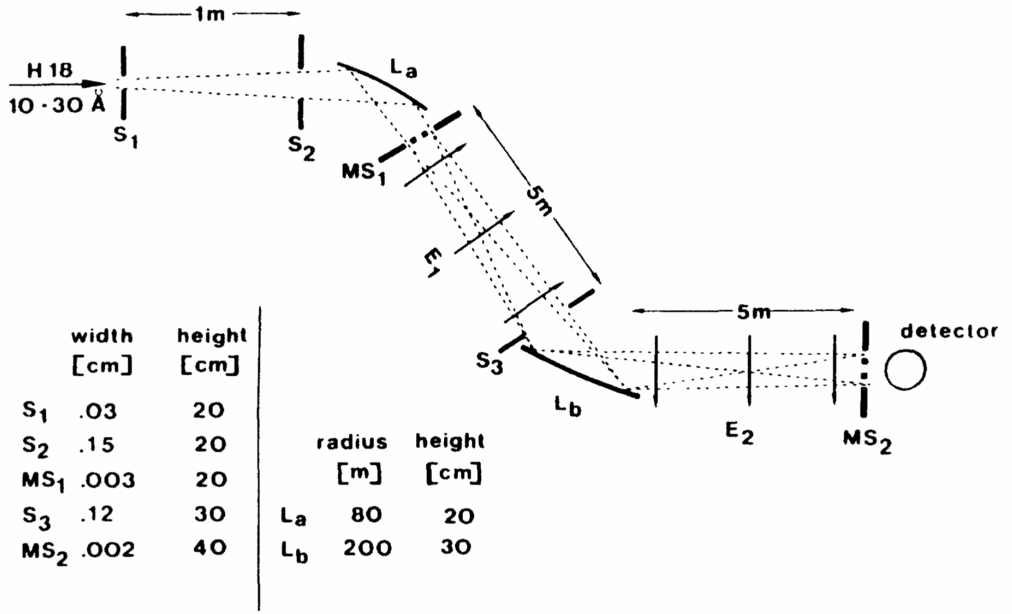
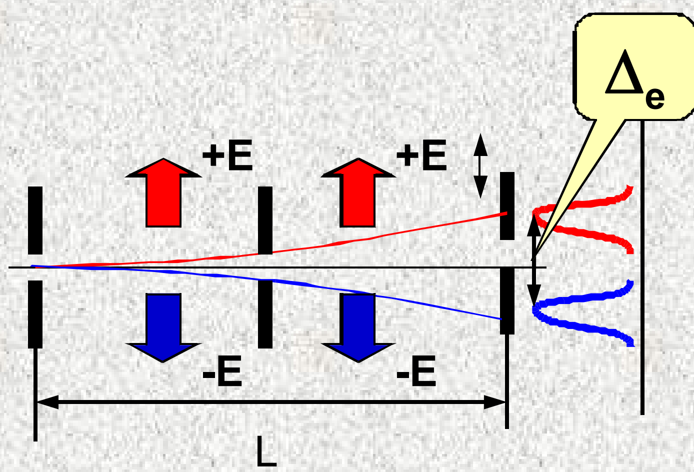


FIG. 1. The design of the deflection apparatus. MS_1 and MS_2 is a multislit system with 31 slits, 30 μm wide, separated by 30-μm-wide absorbing zones. For clarity the dimensions and angles of deflection are not to scale.

λ = 17.5 Å, L = 9 m, E = 60 kV/cm

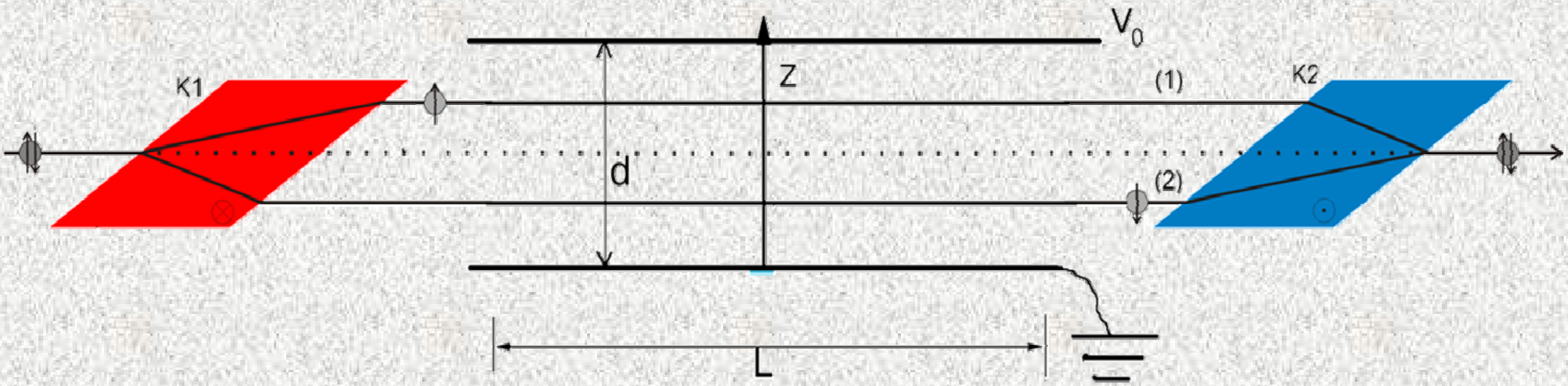
$$q_n = q_e\,(-0.4\pm1.1)\cdot 10^{-21}$$



$$\Delta_e = q_n \mathrm{E}/2E_n \cdot L^2 / 2$$

$$\Delta_e[cm] = q_n \mathrm{E} \cdot 0.75 \cdot 10^9$$

Neutron electric charge



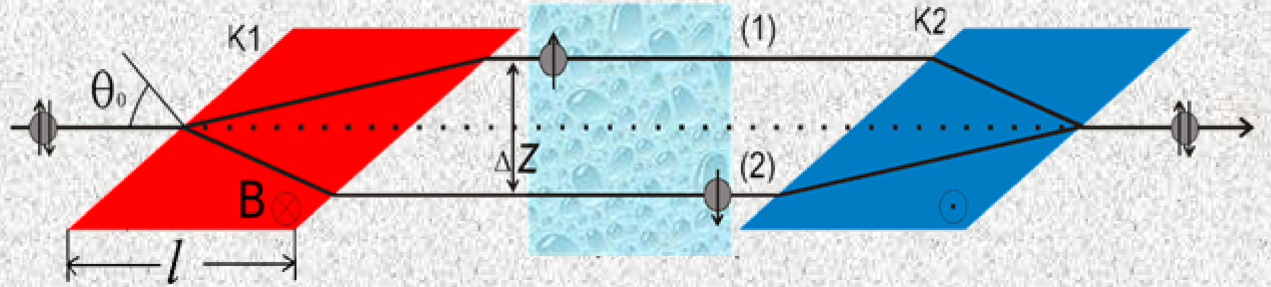
If electric potential $V_E(z)=E_0 \cdot z$ is applied in working area

where $E_0=V_0/d$ - the electric field,

then spin rotation angle will be:

$$\phi_e = \frac{E_0 q_n \Delta Z}{\hbar} \cdot \tau \quad \text{where} \quad \tau = L / \mathrm{v}_n = \frac{L \lambda_n m_n}{\hbar 2\pi}$$

$$\Delta Z = \frac{\lambda_n^2 l B \tan(\theta_0)\gamma m_n}{4\pi^2\hbar}$$



where l – K1 coil dimention, θ_0 – angle between the neutron velocity and normal to coil edge, B – value of magnetic field inside the coil, γ –gyromagnetic ratio for the neutron.

Finally, we have

$$\phi_e = E_o q_n l L B \tan(\theta_0)\gamma \frac{\lambda_n^3 m_n^2}{8\pi^3\hbar^3}$$

and $\phi_e \sim \lambda_n^3$

Numerical estimations

Let's introduce:

B=0.1T, L=1м, l=1м, E_0=100кV/cм, tan(θ_0)=10, λ_n=30Å)

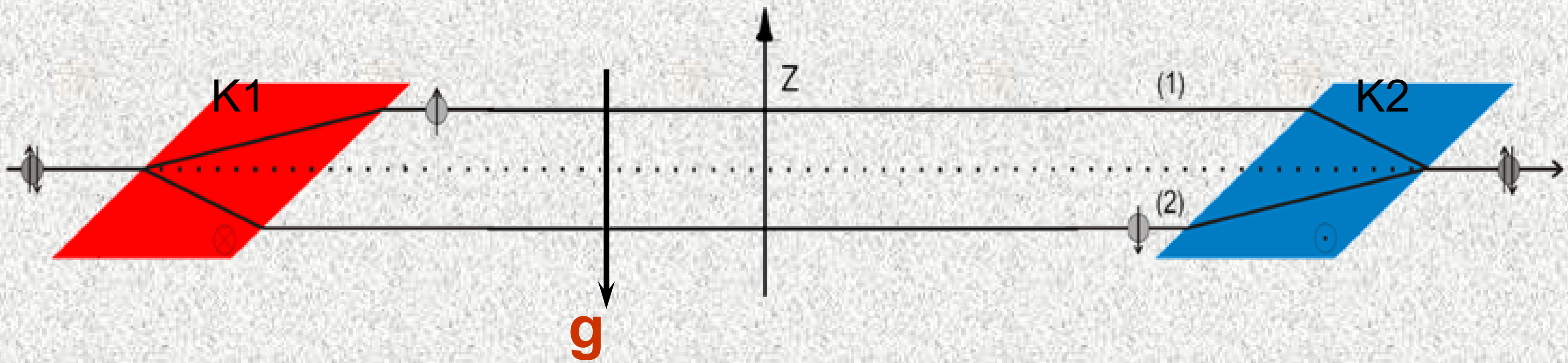
ΔZ = 0.065 cm and $\phi_e = 7 \cdot 10^{16} e_n$

where $e_n = q_n/e$ –neutron electric charge in elementary charge unit.

Accuracy of $\Delta\varphi_e \sim 10^{-5}$ → $\sigma(e_n) \sim 1{,}4 \cdot 10^{-22}$

i.e. order of magnitude better than previous result

Problem of gravity

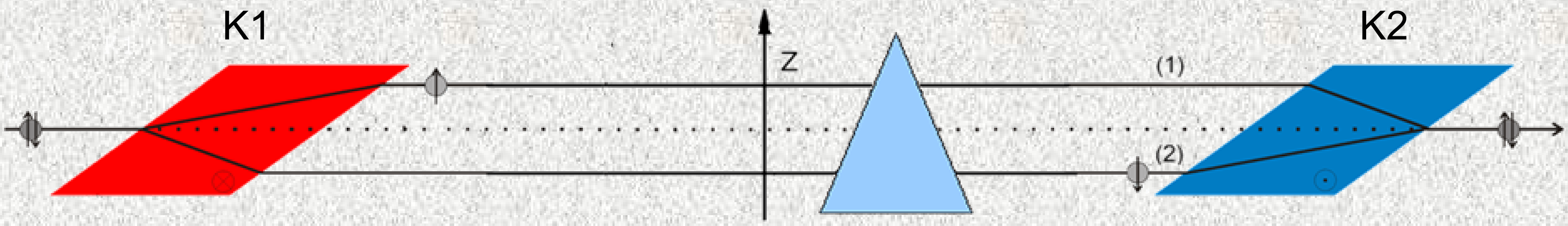


For neutron $F_G = 10^{-9}$ *[eV/cm]* *and* $\Delta V_G = 10^{-9} \cdot \Delta Z$ *[eV]*

$$\phi_G = \frac{\Delta V_G \cdot \Delta Z}{\hbar} \cdot \tau = 10^{-9}[eV/cm] \cdot lLB \tan(\theta_0) \gamma \frac{\lambda_n^3 m_n^2}{8\pi^3 \hbar^3}$$

$$\phi_G = 6{,}5 \cdot 10^2 \, rad\,!$$

Test experiment with the wedge



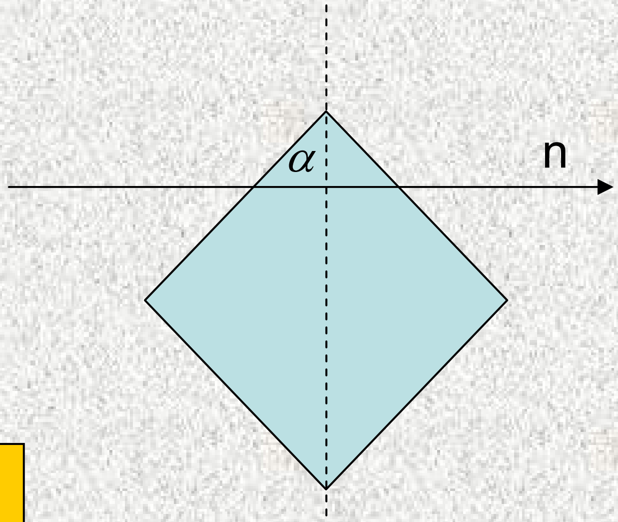
SESANS PNPI characteristics:

$\lambda = 0.23nm$ $\quad$ $l = 0.5m$

$\Delta\lambda / \lambda = 0.02$ $\quad$ $\theta = 45^\circ$

If **B=0.04T** → **ΔZ = 200 nm**

The wedge – quartz crystal (SiO_2)
5 x 5 x 2 cm^3



$$\phi = \frac{1}{2}\frac{U_0}{E} \cdot k \cdot \Delta L$$

where U_0 – nuclear potential, E – neutron energy,
k – wave vector, ΔL – neutron path difference.

$$U_0 = \frac{2\pi\hbar^2}{m}\frac{1}{V_c}\sum_i a_i \approx 10^{-7} eV$$

$$\Delta L = \Delta Z \cdot 2\tan\alpha = 400nm$$

$$\phi = 3 \cdot 10^{-2}$$

Near plans and tasks

- Test experiment with the wedge
- Computer simulation with McStas, VITESS etc.
- Real experiment – where to do, how to do?
  WWR-M, Delft, PIK?

Thank You