CRYSTAL SCIENTIFIC PUBLISHERS

Research Article

Crystal Journal of Physics

Neutron Measurement of Moisture in Mineral Matter. Physical Side of the Gauge

Servo Kasi*

Aalto University and home: Fi-01360 Vantaa, Finland

Corresponding Author: Servo Kasi, Aalto University and home: Fi-01360 Vantaa, Finland.

Cite: S. Kasi, "Neutron measurement of moisture in mineral matter. Physical side of the gauge," Crystal Journal of Physics, vol. 2, no. 1, pp. 1-5, 2026.

Received: October 29, 2025; **Accepted:** December 22, 2025; **Published:** January 02, 2026

Abstract
This measurement depends on the hydrogen slowing-downs of fast neutrons. Except moisture in good measurements one then considers the parameters: hydrogen content, density and absorption cross section of the matter. For this meter I have made Monte Carlo (MC)-calculations [1], the first with Elliott [2] and the last ones with MatLab in my computer. I have supposed a point source S and point detector D in infinite medium. In the actual calculations, at first, I have taken the AmLi source spectrum of neutrons [3] to pick up the energy for each neutron. The neutrons I follow downwards sequentially. They slow down to the energy E_0 = 1217 eV. q_0 is the slowing-down density at the energy E_0.

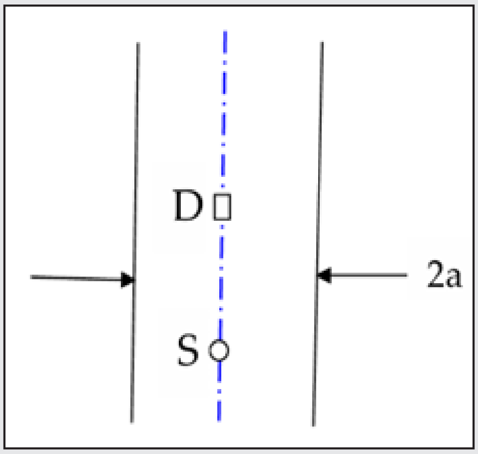
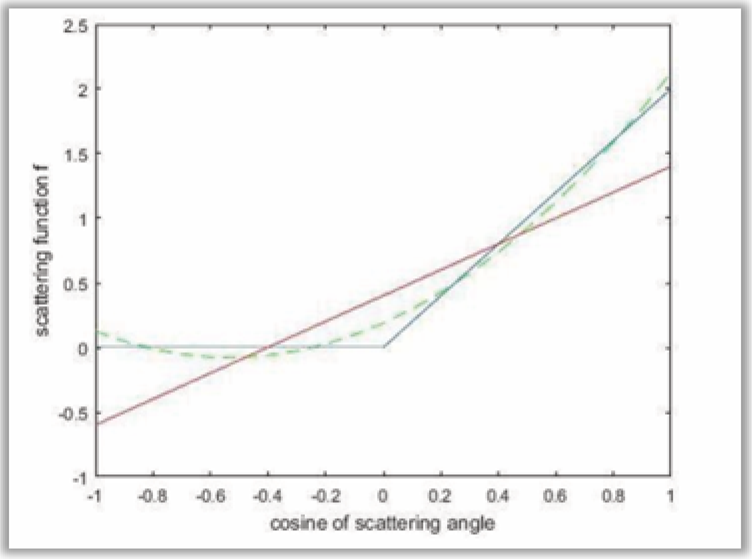


***Figure 1:** Neutron meter of moisture*

Now also another MC-calculation is needed. That is: starting from the detector D with neutron energy 0.6 eV (epithermal meter) and energy goes upwards. At 1217 eV I find the value for $\boldsymbol{\Phi}^*$*, the adjoint or may be called the quantity of detection. Now in a scattering event the energy and weight of "pseudo- neutron" grow. For hydrogen scattering $E_2=E_1/r$. r is random number (0…1]. The first adjoint MC program MCNA is from the year 1971 [4].*

$q(\boldsymbol{r},\boldsymbol{\Omega})$ *from S and* $\boldsymbol{\Phi}^*$**0(r,$\boldsymbol{\Omega}$) from D have spherical geometry. They will be multiplied and shall be integrated in cylindrical geometry: r > a and z = (-∞,+∞). The* $\boldsymbol{\Omega}$*s one must consider properly.*

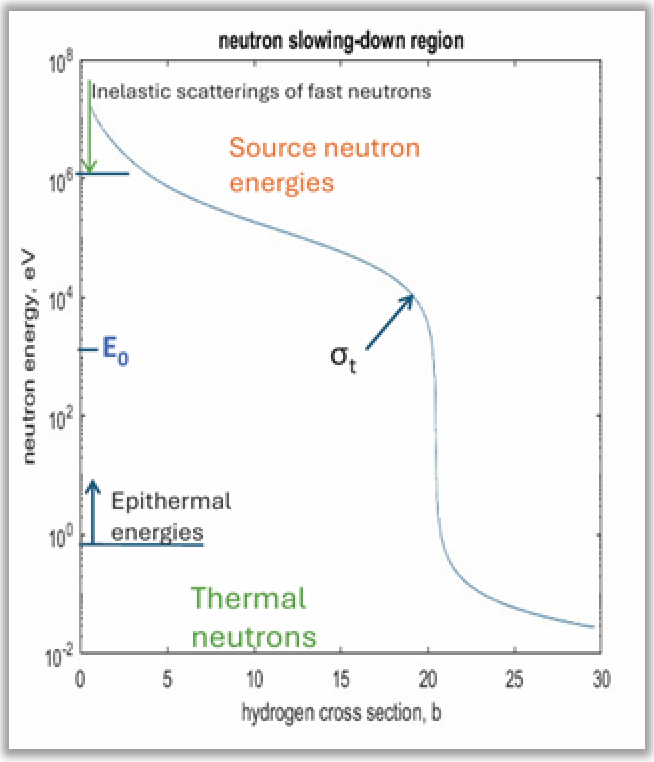


Neutron scattering in hydrogen (blue line). Its P1-approximation is the red line, In the figure is also the P2(P3) approximation (dashed).

P1: Diffusion Approximation. Total hydrogen crossection $\sigma_t = \sigma_s + \sigma_a$. $\sigma_a << \sigma_s$

Below 1 MeV other Elements than hydrogen slow-down negligibly.

I try to find a model for the measurement by using MC calculation. I use traditional forwand calculation in slowing-down, but also the upwards calculation, from thermal or epithermal energies upwrds in energy.



$$c = \int_V \int_{4\pi} \Phi^*{}_{E_0}(\boldsymbol{r}, \boldsymbol{\Omega}) q_{E_0}(\boldsymbol{r}, \boldsymbol{\Omega}) d\boldsymbol{\Omega} d\boldsymbol{r}$$

c counting rate
q_E slowing-down density
$\boldsymbol{\Omega}_{*E}$ detection quantity or adjoint flux of pseudo neutrons

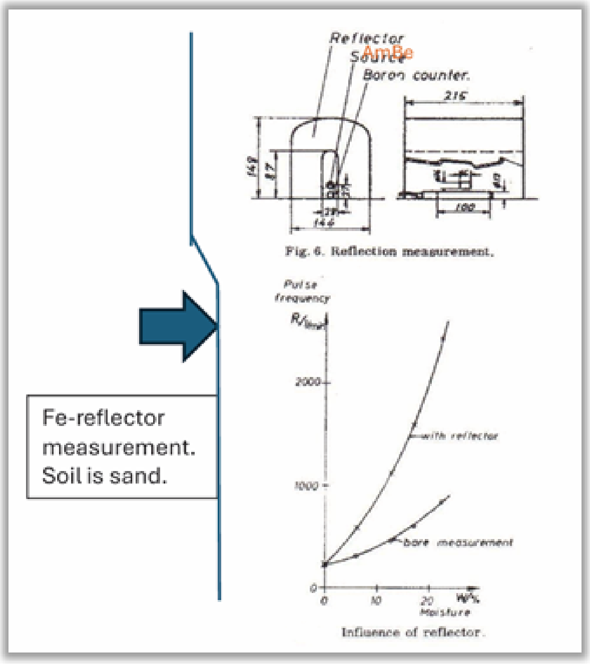
This measurement depends on the hydrogen slowing downs of fast neutrons. The detector measures thermal or epi thermal neutrons

Except moisture in good measurement one considers the parameters:

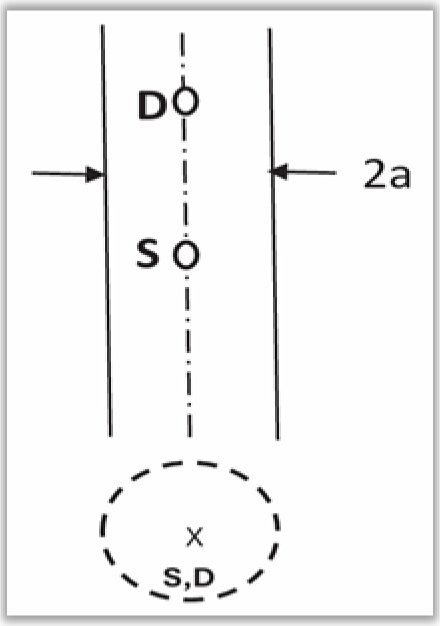
- hydrogen content of matter (dry)
- density of matter
- σ absorption cross section especially in thermal detection

Neutron sources:
n-generators:
DT 14 MeV, T(d, n) ^{4}He
DD 2.5 MeV, D(d, n) ^{3}He
$^{252}Cf, t_{1/2}$. = 2.646 a
^{241}Am (α,n)^{9} Be, ^{41}Am (α,n) ^{7}Li etc.
For ^{241}Am $t_{1/2}$. 432.2a

The inelastic scattering of iron reduces the energies of fast neutrons



In Calculations soil has elements as in Earth's crust, and its dry density is 1.5e3 kg/m3.



I supposed, that point source S and point detector D are in infinite soil. Around the points there are shells.

But the shells from S and from D do not coinside. Therefore, I set the distance SD = 0. I try to find the good shell radia.

Now r = 0, 1.19, 1.42, 1.69, 2.02 = a, 2.40, etc. Epithermal detection I suppose.

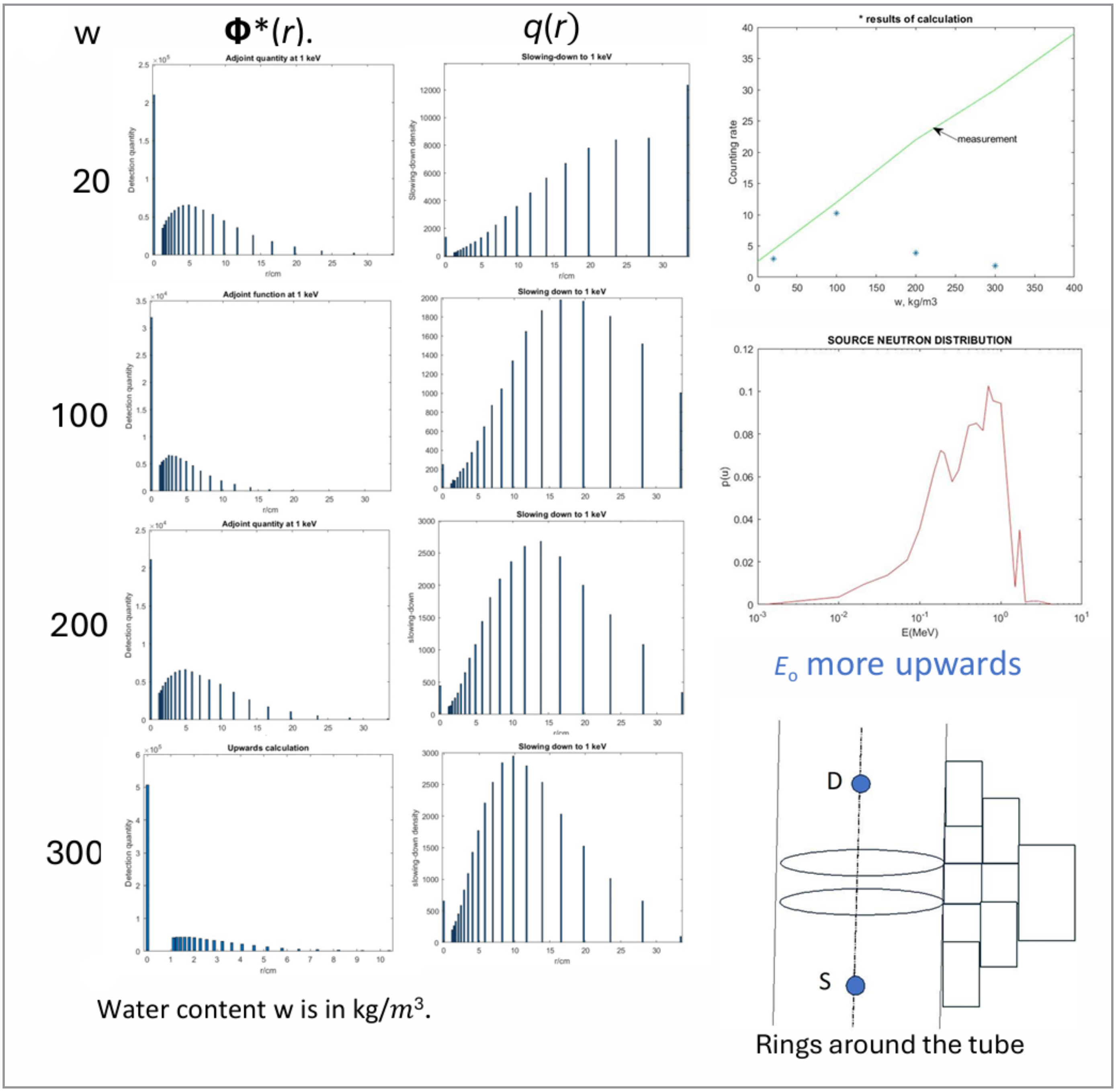
Neutron comes to the detector. There is an event. The neutron has had a path. You can follow the path. This is MC calculation upwards in energy. You calcute the paths of the pseudo-neutrons. Suppose ^{6}Li detection.

You have 2 MC calculations: one downwards from the source energies and one upwards from detection energies. I selected E0 = 1 keV is the energy where the paths meet: you determine the slowing-down density $q(r,\boldsymbol{\Omega})$ and adjungate function $\boldsymbol{\Phi}^*(r,\boldsymbol{\Omega})$. these are summed up over the shells to get to counting rate c or CR.

I Selected the detection propability $D \sim \frac{1}{\sqrt{E}}$. $X = E/E_1$ where E_1 = 0.6eV, kadmium-edge.
To find X, and E, when r ⊂ [0..1] is random number, it is to solv the equation

$$r = \int_1^x 1/\sqrt{x}\; dx$$

In hydrogen scatterings;
downwards $E_2 = rE_1$
upwards $E_2 = E_1/r$



References

1. Cashwell, E.D. and Everett, C.J. (1959) A Practical Manual on the Monte Carlo Method for Random Walk Problems. Pergamon Press, Oxford.
2. S. Kasi and H. Koskinen, "Analysis, calculations and measurements concerning the moisture measuring by the neutron method," *Nuclear Engineering and Design*, vol. 3, no. 1, pp. 74–82, Jan. 1966, doi: 10.1016/0029-5493(66)90150-6.
3. A. V. Mozhayev, M. E. Moore, and E. K. Mace, "Characterization of two extraordinary AmLi neutron sources," *Applied Radiation and Isotopes*, vol. 168, p. 109472, Feb. 2021, doi: 10.1016/j.apradiso.2020.109472.
4. C. Josey and A. Sood, A Review of 70 Years of Monte Carlo Development at Los Alamos: 1953–2023. Los Alamos National Laboratory, LA-UR-23-27907, Jul. 2023. Presented at the International Topical Meeting on Industrial Radiation and Radioisotope Measurement Applications (IRRMA), Bologna, Italy, Jul. 21, 2023.