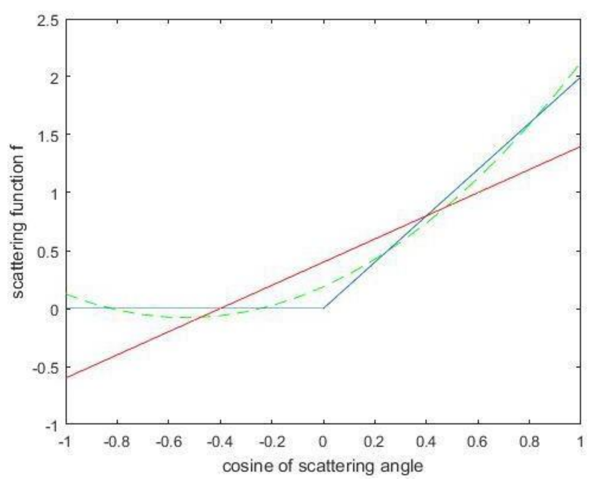
Neutron Measurement of Moisture in Mineral Matter

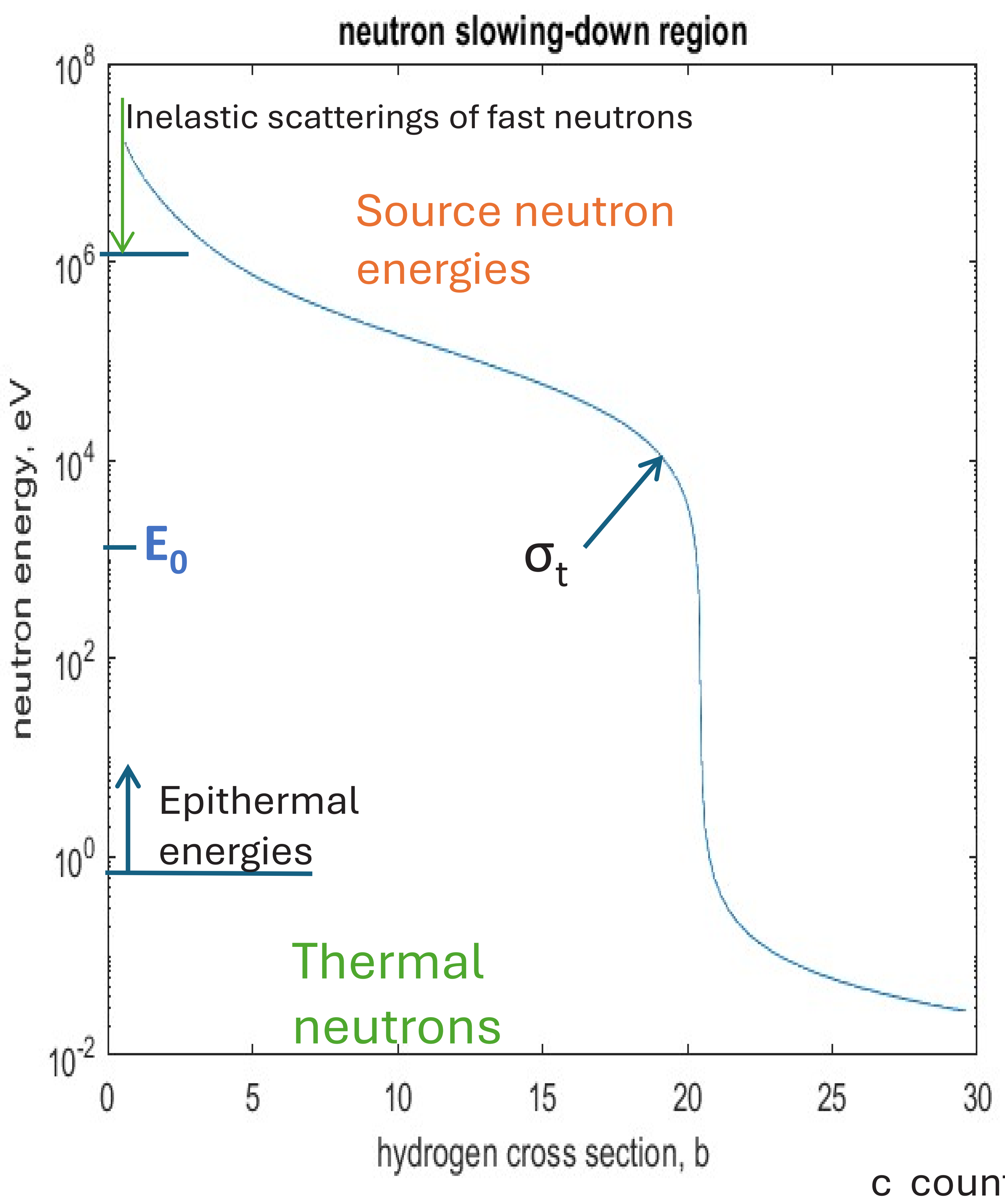
Servo Kasi, Aalto University, Finland

Avoid systematic errors



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



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:

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

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 forward 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

$\boldsymbol{\Phi}^*{}_E$ detection quantity or adjoint flux of pseudo-neutrons

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 $t_{1/2}$.= 432.2 a

The inelastic scattering of iron reduces the energies of fast neutrons.

Fe-reflector measurement. Soil is sand.

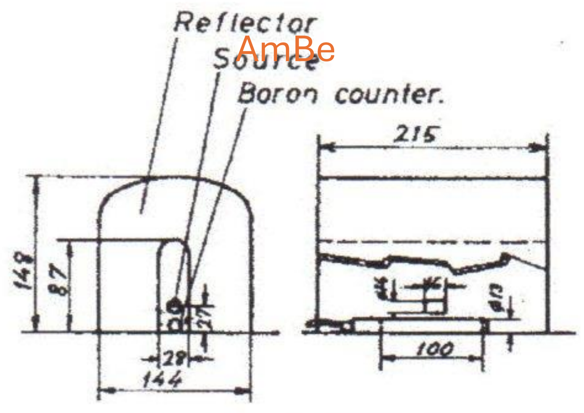


Fig. 6. Reflection measurement.

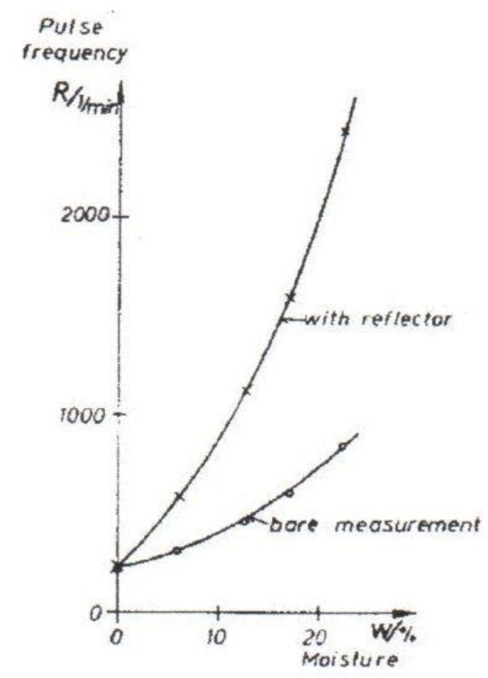
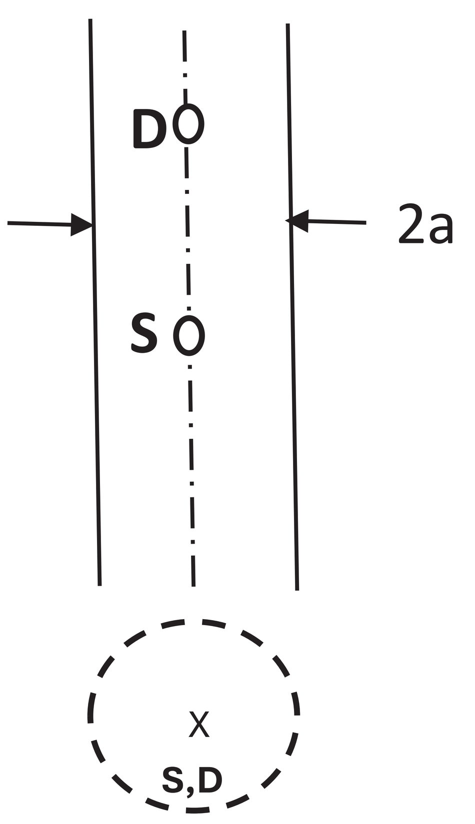


Fig. 7. Influence of reflector.

In calculations soil has elements as in Earth's crust, and its dry density is 1.5e3 kg/m^3.



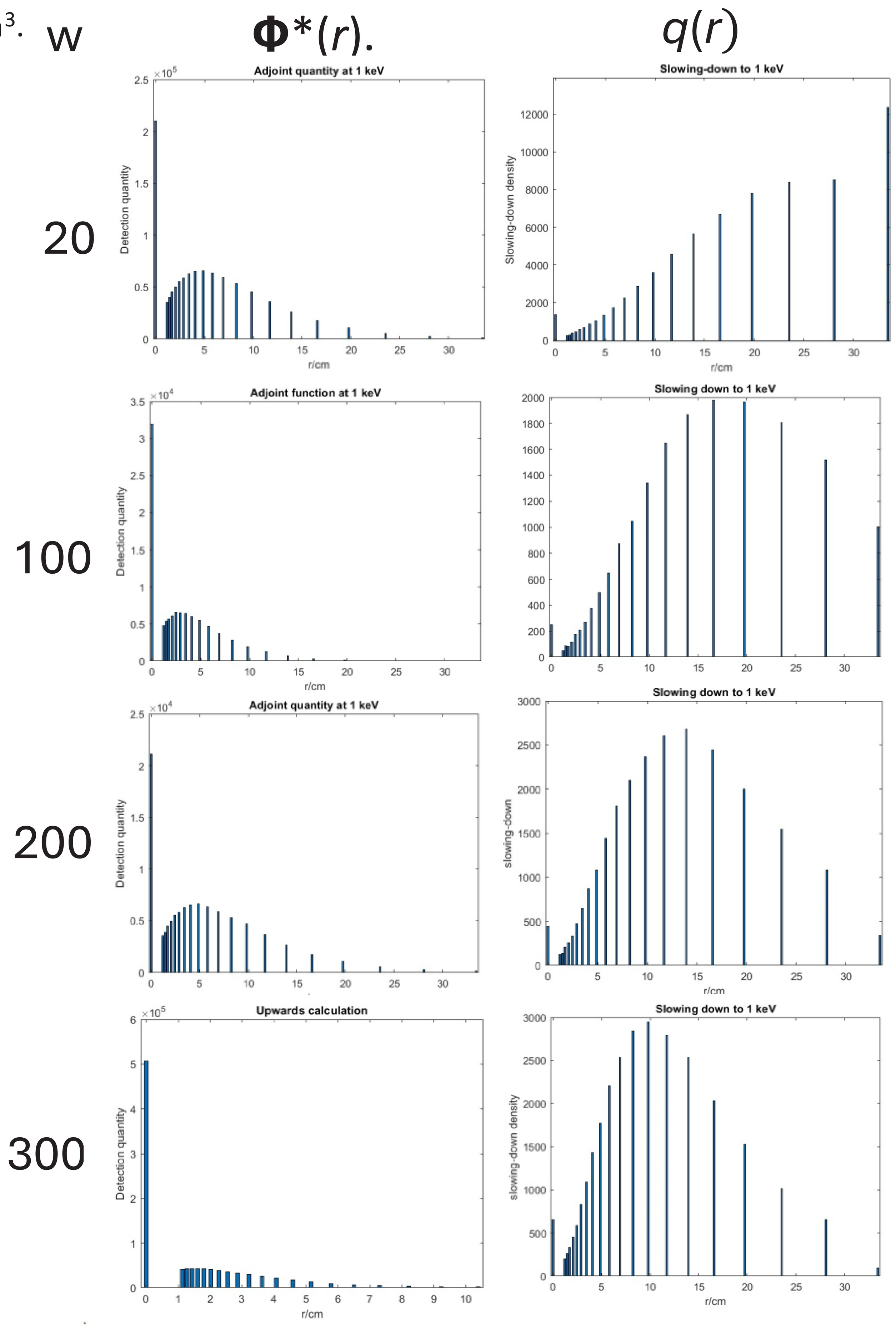
I supposed, that point source S and point detector D are in infinite soil. Around the points there are shells. But the shells from S and from D do not coinside. Therefore I set the distance SD = 0. I try to find the good shell radia. Now r = 0, 1.19, 1.42, 1.69, 2.02 = a, 2.40, etc. Epithermal detection 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.

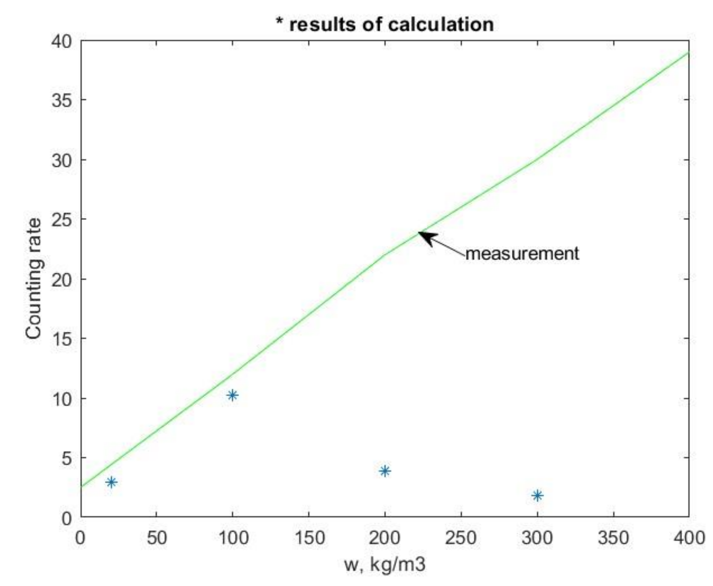
You have 2 MC calculations: one downwards from the source energies and one upwards from detection energies. I selected E_0 = 1 keV is the energy where the paths meet: you determine the slowing-down density $q(r,\boldsymbol{\Omega})$ and adjungate function $\boldsymbol{\Phi}^*(r,\boldsymbol{\Omega})$. These are summed up over the shells to get the counting rate c or CR. I selected the detection propability $D \sim \frac{1}{\sqrt{E}}$. $X = E/E_1$ where E_1 = 0.6 eV, kadmium-edge. To find x, and E, when r ⊂ [0..1] is random number, it is to solv the equation

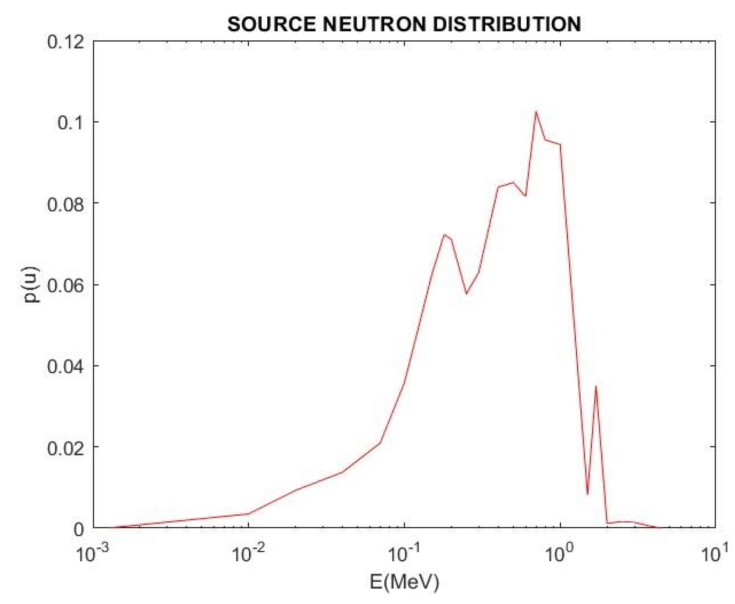
$$r = \int_1^x 1/\sqrt{x}\, dx$$

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

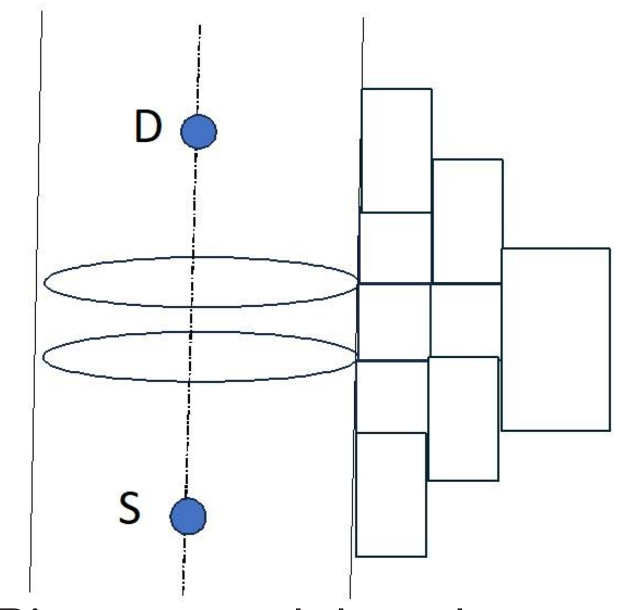


Water content w is in kg/m^3.





E_0 more upwards



Rings around the tube