The solid particles in soils form a complex network of voids that determines the storage and flow of water and the transport of dissolved substances. The larger these voids, in the following denoted as pores, the higher the water flow velocity and the smaller the capillary forces avoiding air entry. In small pores, water flow is slow due to the friction at the solid walls but they remain water filled due to the high capillary forces. So, to predict the flow and the distribution of water, the size of the pores must be known. In soil physics, the size of the pores is determined indirectly by measuring the water volume remaining in the soil, when a pressure is applied to the soil water to overcome the capillary forces. For an applied pressure \( p \), only pores of radius \( r \) fulfilling the following condition remain water filled

\[
r < \frac{2\sigma}{p}
\]

with the surface tension of water \( \sigma \) [kg s\(^{-2}\)]. Such an indirect measurement is flawed by the fact that large pores with weak capillary forces may be surrounded by small pores that prevent the air intrusion. Therefore, we need a method to measure the size of the pores directly. Four different cylindrical samples of 15mm in diameter were prepared containing fine and coarse sand material. The measurement of the pore sizes with a resolution of 11microns was performed at the beamline W2 at HASYLAB. The particle sizes range from 0.1 to 0.5mm for the fine and from 0.3 to 0.9mm for the coarse sand. Natural soils contain different materials that may be arranged in complex patterns. To analyze the geometric properties at the boundary between different materials, two samples were prepared with vertical or horizontal layers, while two samples contained pure material. Vertical cross sections through the four samples are shown in Figure 1.

After the reconstruction of the data, a cubic section of 500\(^3\) voxels was segmented into pores and grains and the pore sizes were determined. First, the mean pore size of planes parallel to the boundary was computed: Each pixel is assumed to be the centre of a disk touching the closest grain. A pore pixel, denoted as \( A \), may be an element of different disks that are centred at neighboured pixels. The radius of the largest of these disks determines the pore size of pixel \( A \). Then, the mean value of the size of all pore pixels in a plane is calculated. In Figure 2A, the mean pore radius as a function of the distance from the boundary is shown for the layered materials. The thickness of the transition zone between the coarse and the fine material is about 1mm. Within this transition zone, the hydraulic properties may be different and affect flow and transport properties. To compute the water distribution in the layered media, the three dimensional pore sizes must be taken into account. The three dimensional pore radius is determined using a sphere as probe instead of a disk as in the two dimensional case. The result is shown in Figure 2B for the pure and the layered materials. The pore sizes of the layered media are the average of the pure materials.
After the determination of the pore size, the drainage of the samples was calculated in a numerical experiment. A pressure $p$ was applied at the lower boundary of the initially water filled cubic sample to drain the sands. At the top, air will enter in pores with size $r \geq 2 \sigma / p$ according to equation 1. To drain smaller pores, the pressure was increased stepwise. A water filled pore will drain out when the capillary forces are too weak to sustain the applied pressure and when it is not completely surrounded by smaller pores. To quantify this effect of connectivity with smaller pores, the drainage computed with the numerical model is compared to the cumulated pore size distribution. Without connectivity, all pores of size $r \geq 2 \sigma / p$ would drain out. The comparison is shown in Figure 3.

Compared to the cumulated pore size distribution, higher pressure values are needed in the numerical model before the samples starts to drain out. According to the cumulated pore size distribution, the samples should start to drain out for pressure values between 1’000 and 1’500 Pa. But in the numerical experiment, the drainage begins for values between 1’500 and 2’500 Pa. In addition, about 10% of the pore space remains water filled in all four samples. This occurs, when large pores surrounding small pores becomes air filled and the water within the small pores is isolated and not connected with the lower boundary, where the force is applied to the soil water. Finally, there is a small difference between the curves for the layered materials. The fine sand in the horizontal arrangement drains out for higher pressure values. This is caused by the existence of layers with small pores and higher capillary forces, as indicated by the arrow in Figure 2A.

We can conclude that due to the synchrotron light technology a new insight into the geometry of the pore space is given. In combination with numerical models, the effect of pore size and pore connectivity on water distribution can be analyzed in more detail.