

Manual for the ArborElectro impedance tomograph

December 18, 2018

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Introduction

Welcome as a new ArborElectro owner. ArborElectro is designed to detect inhomogeneous resistivities, impedance inside trees. The ArborElectro Impedance Tomograph is able to detect the size and location of active fungi attacked regions in the trunk non-destructively.

Manufacturer information

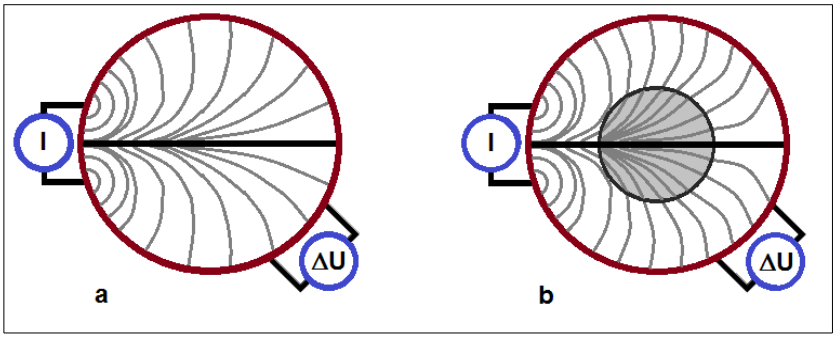
ArborElectro is manufactured by:

Company:	Fakopp Enterprise Bt. together with Geoelectro Kft.
EU tax number:	HU22207573
Address:	Fenyo 26.
City:	Agfalva
ZIP:	9423
Country:	Hungary
Web:	http://www.fakopp.com
E-mail:	office@fakopp.com
Phone:	+36 99 510 996

Principle of operation

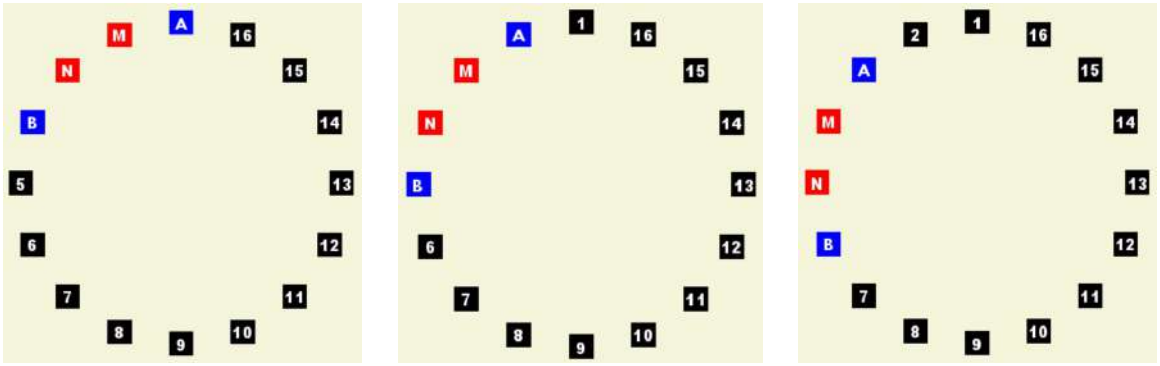
The impedance tomography is in one hand similar to other tomographic evaluations. In the other hand, in this case electricity is conducted to the wood and electric resistivity is measured. The electric field behaves different comparing to acoustic or ultrasonic signals so the measurement can highlight other conditions of the wood. The technique itself originates from geophysics. With proper modifications the measurement can be applied to living trees well.

Change in the measured electric resistivity can refer to more or less water or ion concentrate, red heart (false heartwood) and damages or the presence of fungi. Discoloration of wood, water transport, the sapwood, and the heartwood can be studied by impedance tomography. Early changes in wood can be caught. The impedance tomography shows differences even when the density is still has not changed during a fungi attack, it can catch the infection before the other tomography methods.



a) Schematic image of equipotential lines during an impedance tomography measurement. Current is conducted ("I") to a homogeneous material while the voltage is measured ("ΔU"). The voltage measurement can go around and the role of the electrodes can be changed. A model about the conductivity or resistivity of the material can be made.
b) Schematic image of impedance tomography of a trunk. The change in the material changes the equipotential lines and the measured voltage.

During a measurement electrodes are placed on the tree. (The electrodes have to go through the bark.) Electricity is conducted to the tree by two conducting electrodes (A and B), while the voltage is measured by two detecting electrodes (N and M). Using ArborElectro the usual number of electrodes is 16, 24 or 32. The roles of electrodes are continuously switched during the measurement. (See more details in chapters Software / Measurement and Operation Guide / Measurements.)



The changing roles during a measurement with 16 electrodes

For evaluation the measured the data is analyzed by the software and electric resistivity tomogram is calculated for the measured layer. The resistivity meter measures in Ω * m. (For more information please read chapter Software / Evaluation.)

Components

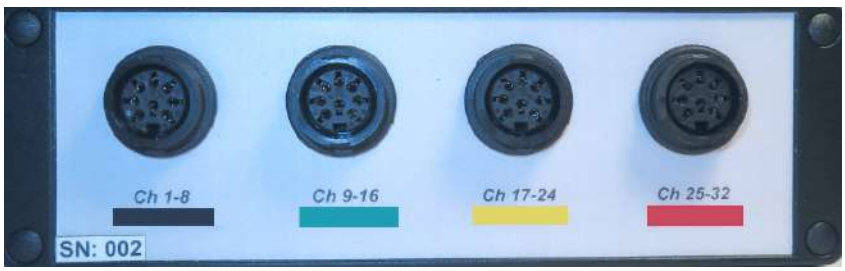
The ArborElectro package contains:

- 1 GeoPic-32 Multielectrode Resistivity Meter
- 1 LEMO-USB connection cable (with 5 needles) to connect the Multielectrode Resistivity Meter to computer
- 1 LEMO-USB charger cable (with 3 needles) to charge the Multielectrode Resistivity Meter
- 4 electrode connecting cable with 8 electrodes on each
- 1 tape measure
- 50 needles (as electrodes) for measurements; diameter: 1.5 mm, length: 63 mm, material: SS304 stainless steel
- 1 steel hammer
- 5 screws to fix the Multielectrode Resistivity Meter onto the tree
- 1 screwdriver
- 1 electrode remover tool
- 1 case

<u>GeoPic-32 Multielectrode Resistivity Meter</u>



The front of the GeoPic-32 Multielectrode Resistivity Meter (without connection to the computer or charger)



The back of the GeoPic-32 Multielectrode Resistivity Meter (without connecting the electrodes)

Specifications

excitation voltage:	5-50V, adjustable in 5V steps
current measurement range:	0-20mA; 0-400µA; 0-40µA
the length of one basic measurement:	640ms
amplifications:	1, 5, 20, 100
inbuilt divider:	1:10

Battery
Built in 5V/5000mAh Li-ion Power Bank

The equipment communicates with the computer with serial port (9600, N, 8). It can be connected with the LEMO-USB cable or with BlueTooth 2.0 (password: 1234).



The LEMO ending has little “spikes” on it, please be careful when removing the cable from the device, please hold the vertical part.

LEMO-USB connection cable





The cable connects the equipment to the computer. Use the blue end to connect it to the resistivity meter at the “USB” input. Look for the red dots for proper connection. The other end of the cable is a USB port, but it will be recognized as a serial port on the computer. (For more information about connection look for sub chapter First connection to computer.)

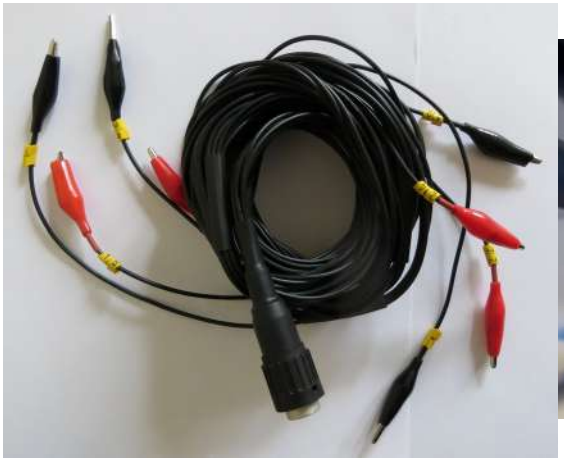
LEMO-USB charger cable





This cable connects the device to any USB ports or chargers for charging. The red end should be connected to the resistivity meter's "Charger" input. Look for the red dots to connect with the proper geometry.
During charging the device should be turned off and a red led will be lighting. (For more information about charging look for sub chapter Charging.)

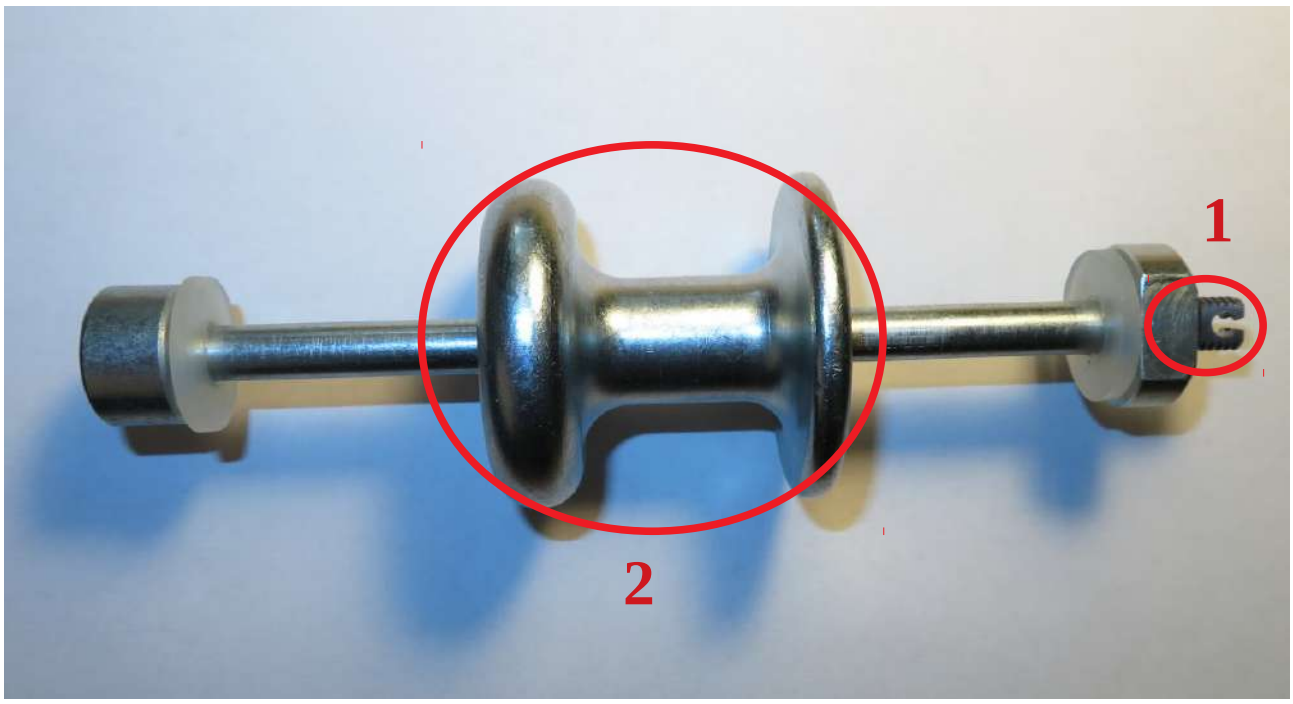
Electrode connection cables



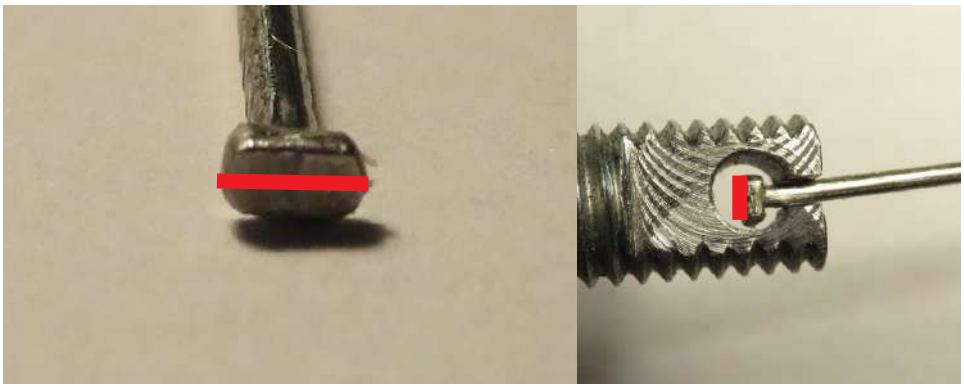


The package contains four electrode connection cables. Each of them includes 8 numbered crocodile clips with black and red colored endings. The main terminal should be connected to the back of the resistivity meter. Take care of connecting the right cable to the proper channels.

Electrode remover tool



Electrodes can be easily removed by this electrode remover tool. Hold the tool as the end of the electrode is in the hole in one end (1). Then quickly push back the moving part (2) towards the other end of the tool. The push removes the needles serving as electrodes without bending them.



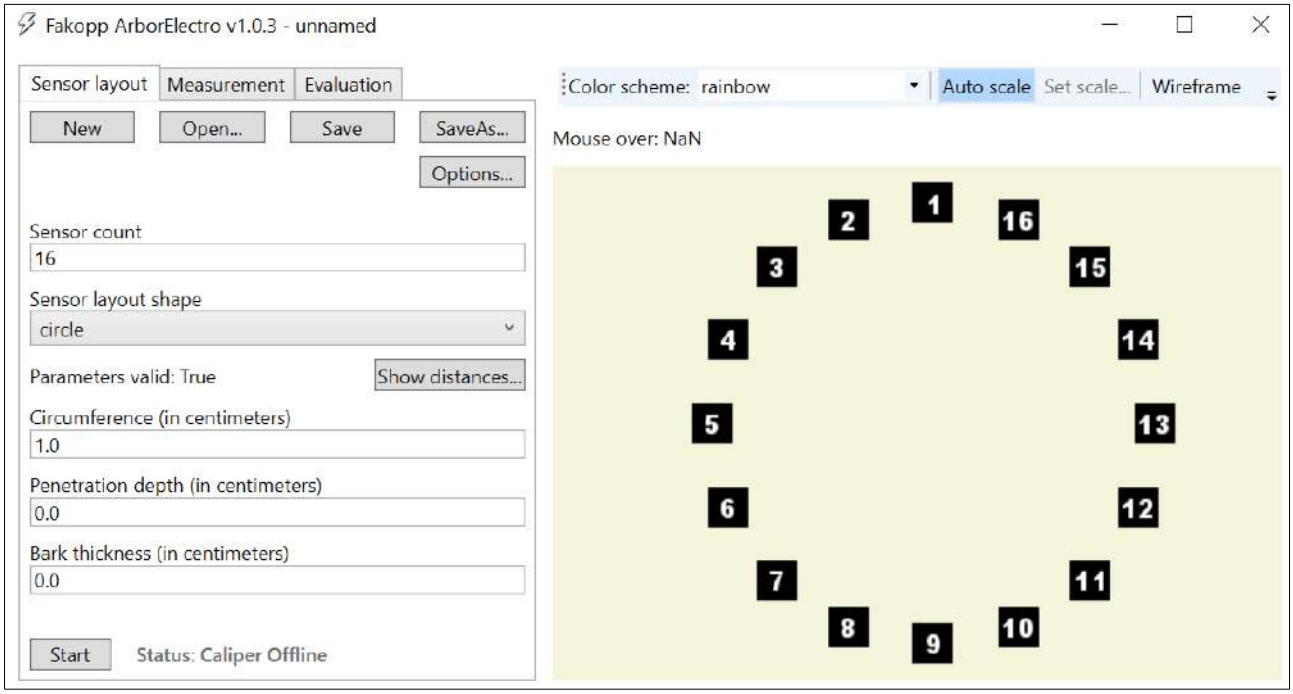
The head of the nails are rectangular. The electrode remover tool can be used only in the proper position.

Software

Sensor Layout

Before measuring please download ArborElectro program. To proceed the software installation: please run the "Fakopp ArborElectro Setup.exe" file. (Supported platforms: Windows Vista SP2, Windows 7 SP1, Windows 8, Windows 8.1, Windows 10. You may have to download or activate .NET 4.6 or higher. https://docs.microsoft.com/en-us/dotnet/framework/install/index)

After you have started the program, you will see the following screen:



The star screen of the ArborElectro program

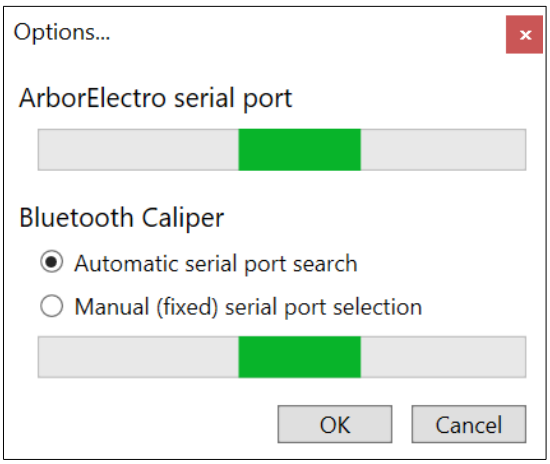
The program starts on the “Sensor layout” tab, where you can start a new measurement or load a previous one for further evaluation.

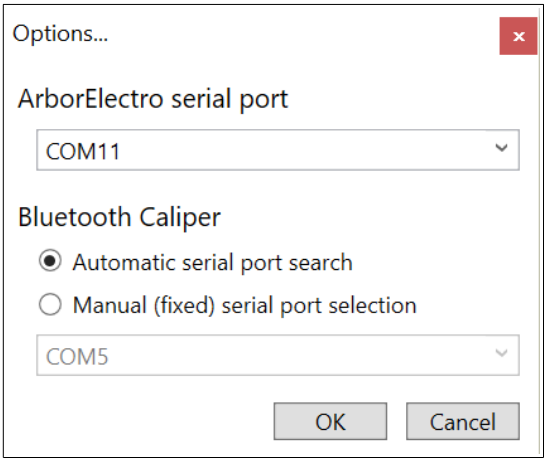
When starting a new measurement it is recommended to push “New” to clean all previous data which could interfere with the current ones.

If you would like to load a previous measurement please select “Open...”

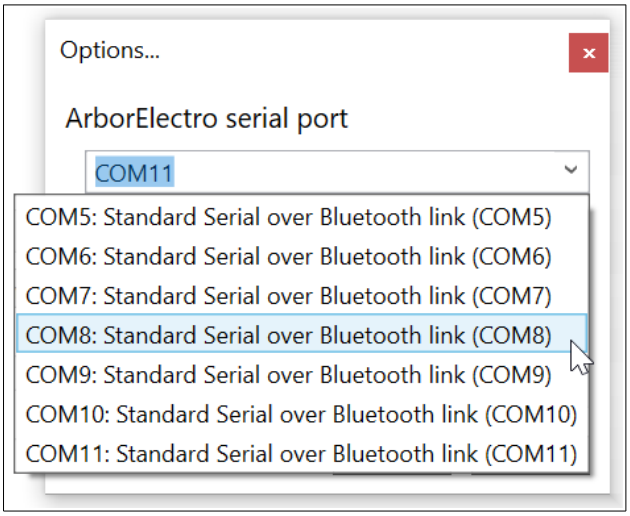
You can save your data with “Save” or “SaveAs...” after geometry registration, measuring or evaluation. The program saves the data into it’s own file format .fae.

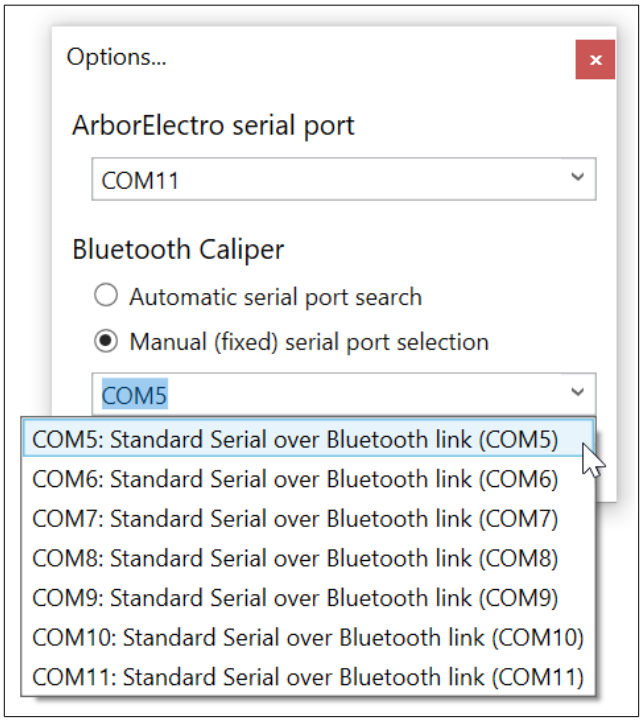
Clicking onto “Options...” button pops up a new window to choose the COM port for the resistivity meter and decide about the options for the Bluetooth caliper.





When you click onto Options… the program searches for the used COM ports. Then it offers you the last used COM port as the COM port for ArborElectro (the resistivity meter) and for the Bluetooth Caliper.





You can change the COM ports in the drop-down lists. For the resistivity meter please look for the COM port which your device got after being paired to the computer. (Details: *Operation guide / First connection to a computer with cable* or *First connection to a computer via Bluetooth* chapters.)

For Bluetooth Caliper you can choose between automatic and manual options. Automatic serial port search listens to all COM ports and delivers the received information to the program (after a quick check to if the information can origin from a Bluetooth Caliper).

Manual (fixed) serial port selection listens only to the selected port. So no noise or other data arriving from other devices (even a second Bluetooth Caliper) will effect the distance data arriving from the paired Bluetooth Caliper.

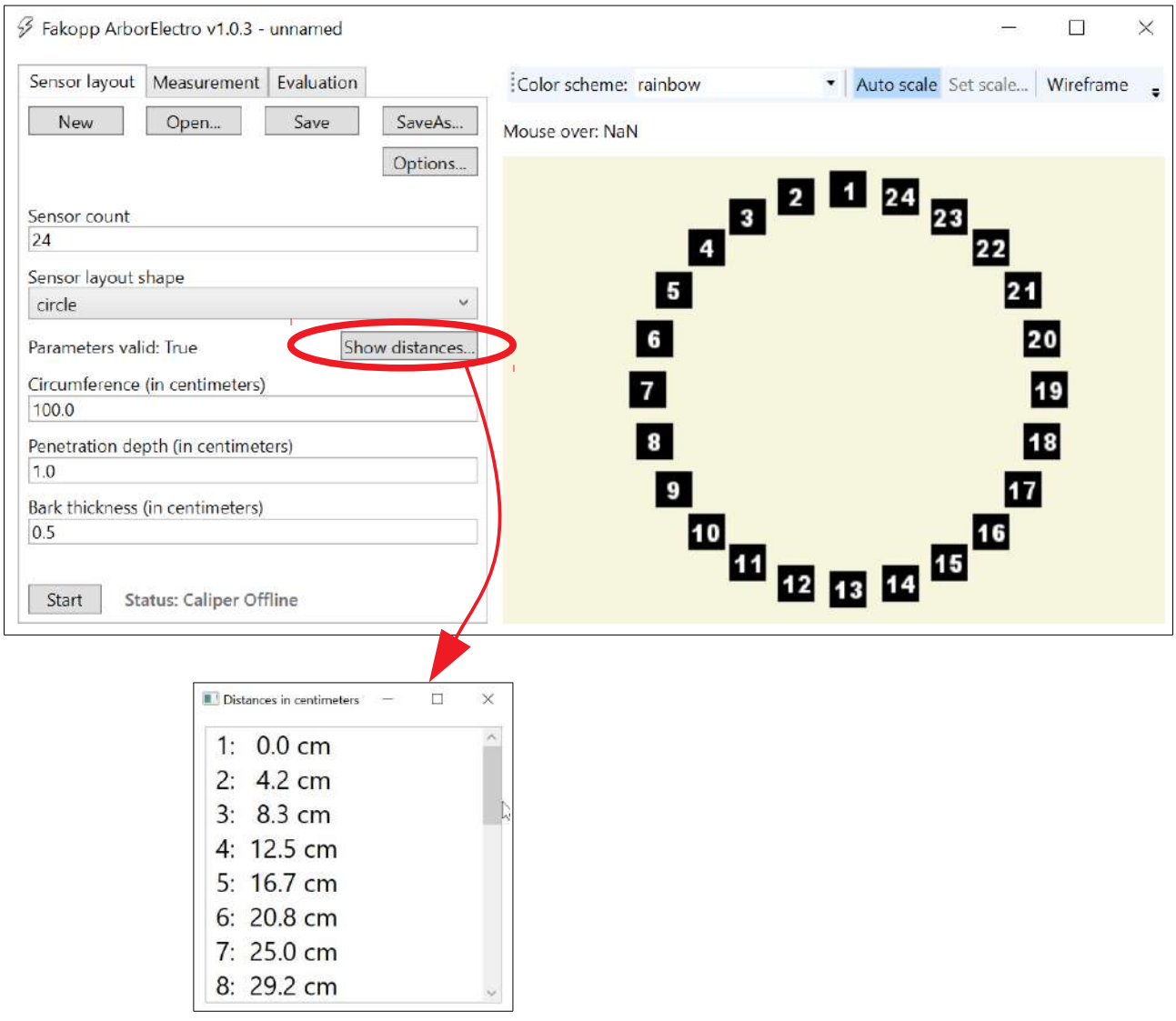
Measurement settings – Sensor Geometry

Select a layer perpendicular to the growth direction for measurement based on visual or other information. When you are going to measure the program will need some data about the trunk, the geometry. First decide about the number of electrodes and enter the “Sensor count”. You can use 16, 18, 20, ... 32 electrodes. Please enter the proper data. (It is not possible to use more than 32 electrodes.)

Next, you have to decide if the trunk is circular, elliptic, or it has an irregular shape.

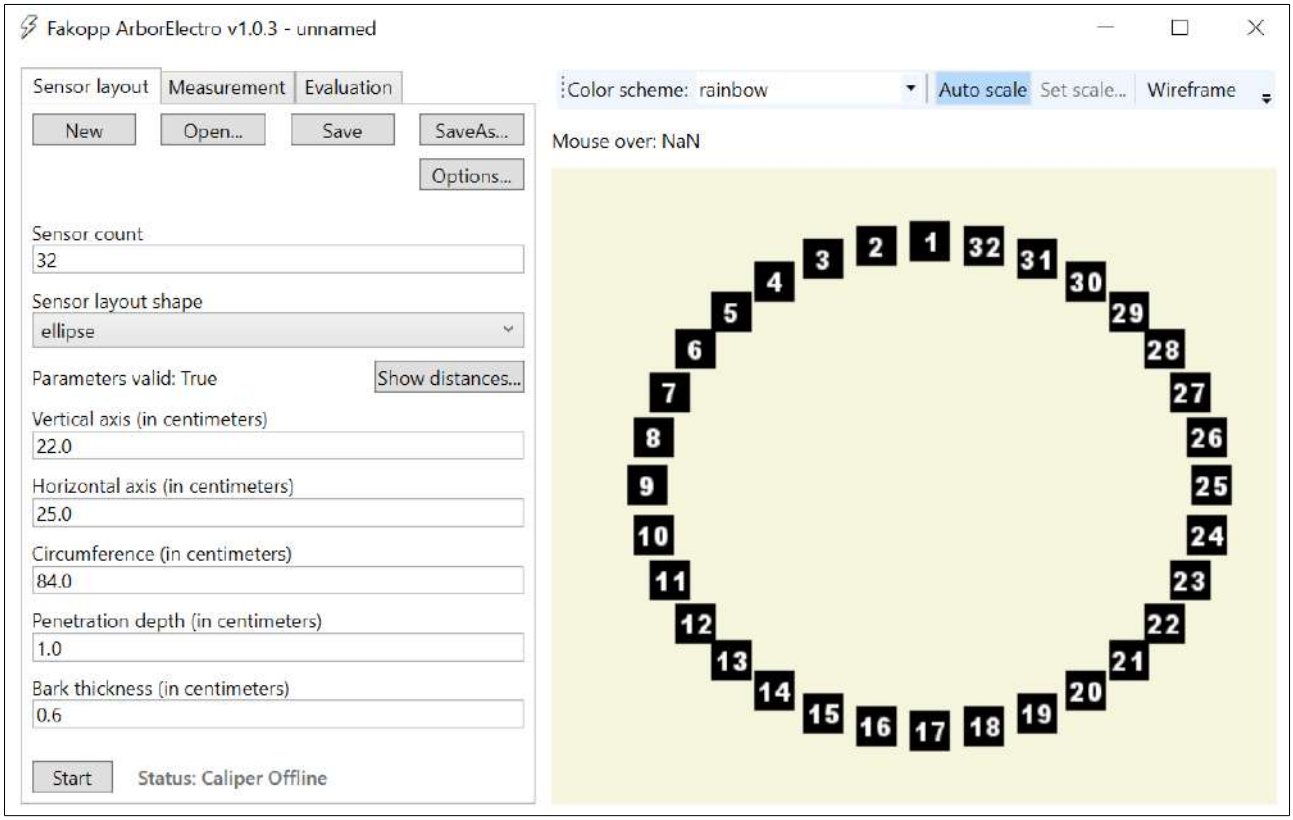
a) Circle

Measure and type in the circumference. Let the tape measure on the tree.
Push the button “Show distances...”
The program calculates the positions of the electrodes. (Place the electrodes onto the tree at the distances shown.)



b) Ellipse

Measure and type in the vertical and horizontal axis, and the circumference. If the data are referring to an existing ellipse, you will see the image of an ellipse on the screen. Let the tape measure on the tree.
(If it is not possible to calculate an ellipse from the data, the “Parameters valid:” will be “False”. If the data are ok, it will be “True”.)
Push the button “Show distances...”
The program calculates the positions of the electrodes. (Place the electrodes onto the tree at the proper positions.)

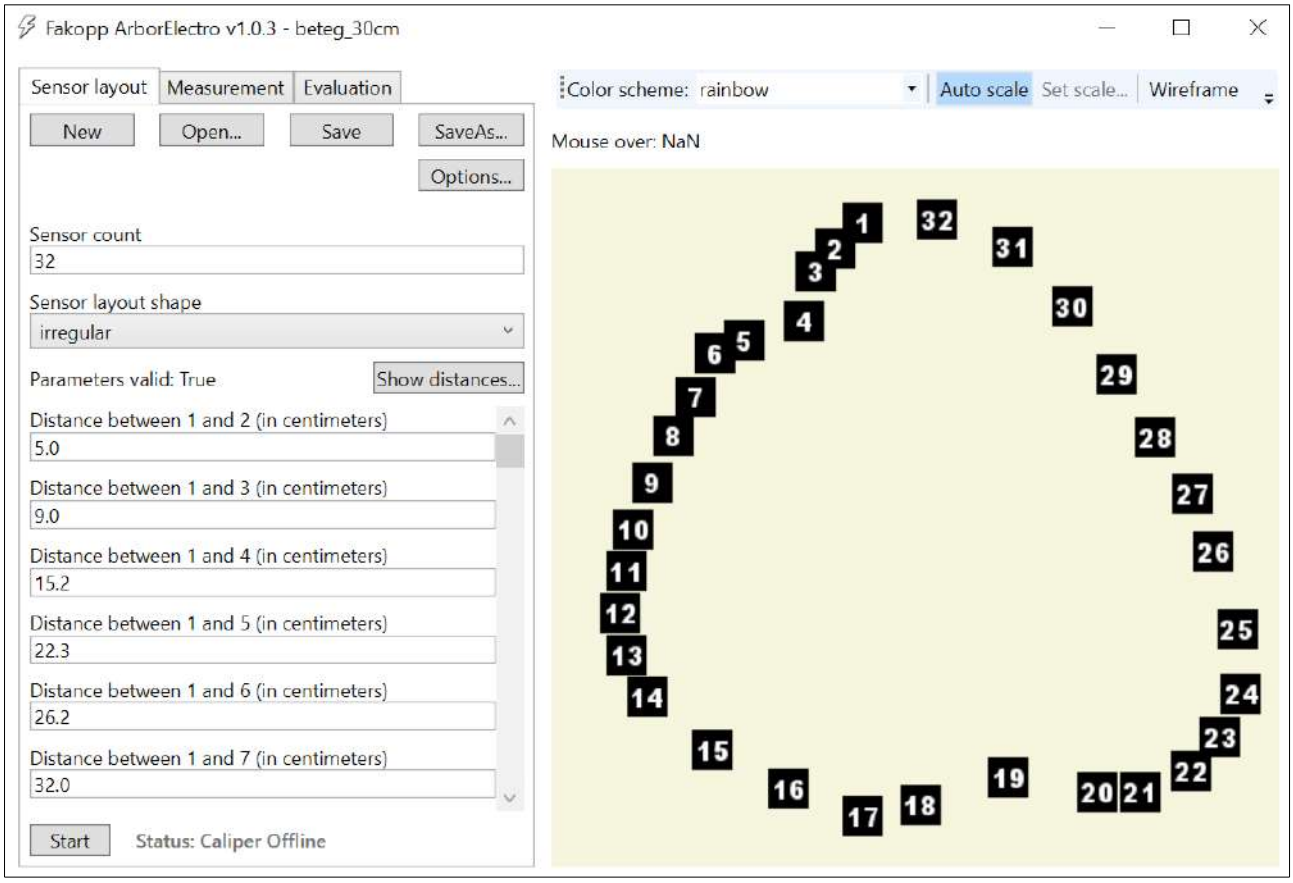


c) Irregular

First you have to put the electrodes onto the tree (look for the advice in sub chapter Measuring irregular shape) then the distances requested by the program should be registered.

The program needs up to 61 distances (in cm-s) depending on the number of the electrodes.

The program calculates the shape and makes a diagram onto the right side of the window with the electrodes.
(If it is not possible to calculate an existing shape from the data, the „Parameters valid:" will be „False". If the data are ok, it will be „True".)



Note: if you choose circular or elliptic geometry and change the geometry to irregular the program calculates the distances of the sensors. It can be very useful if the measured tree is almost circular or elliptic.

For any of the shapes, please add "Penetration depth" (the depth of penetration of the electrodes in centimeters) and "Bark thickness" data (the estimated thickness of the bark in centimeters).

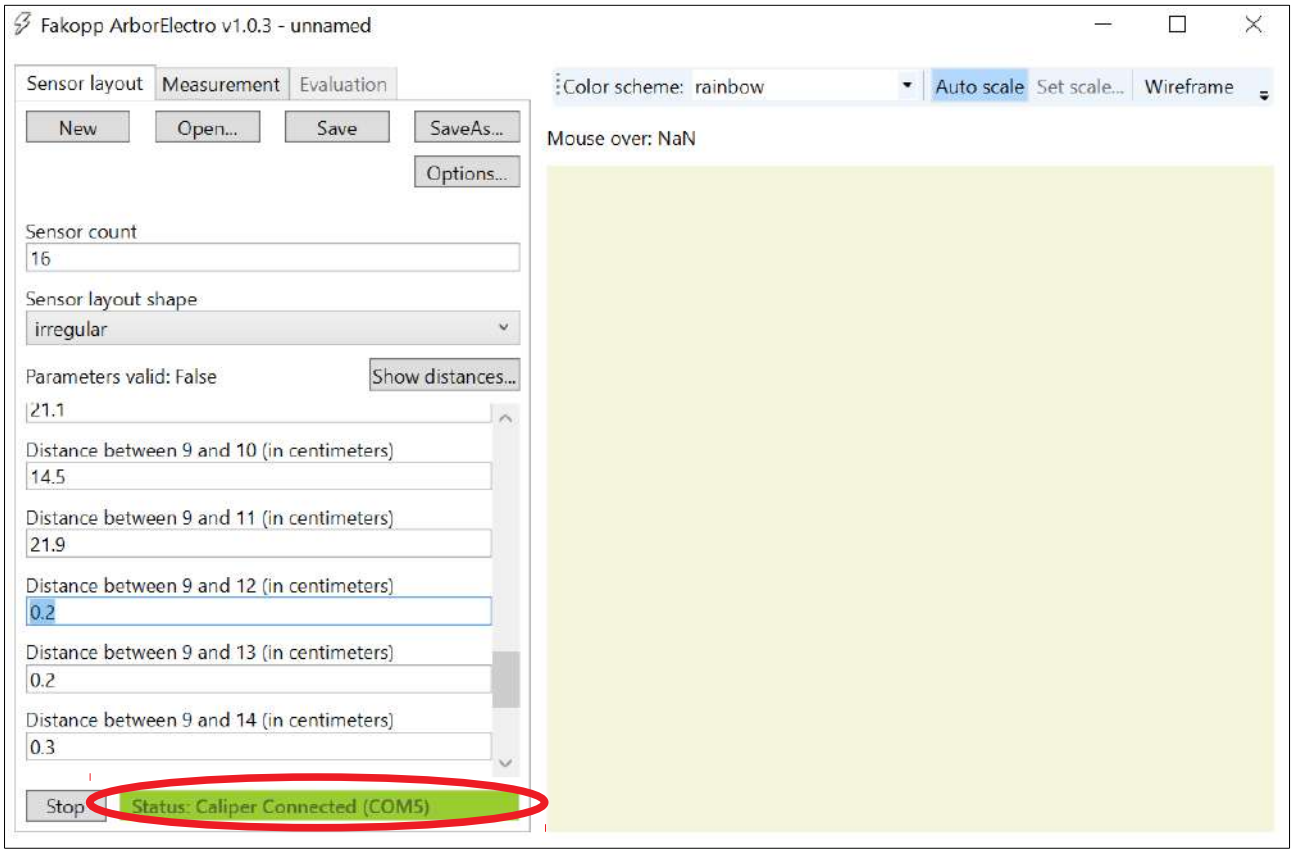
Measuring the distances with Bluetooth caliper

Measuring geometry data like the axis of the ellipse or the distances between electrodes can be measured by a digital Bluetooth caliper as well.

First you should add the Bluetooth caliper as a new Bluetooth device to your system. It is detailed in *Operation guide / First connection to a computer via Bluetooth* chapter.

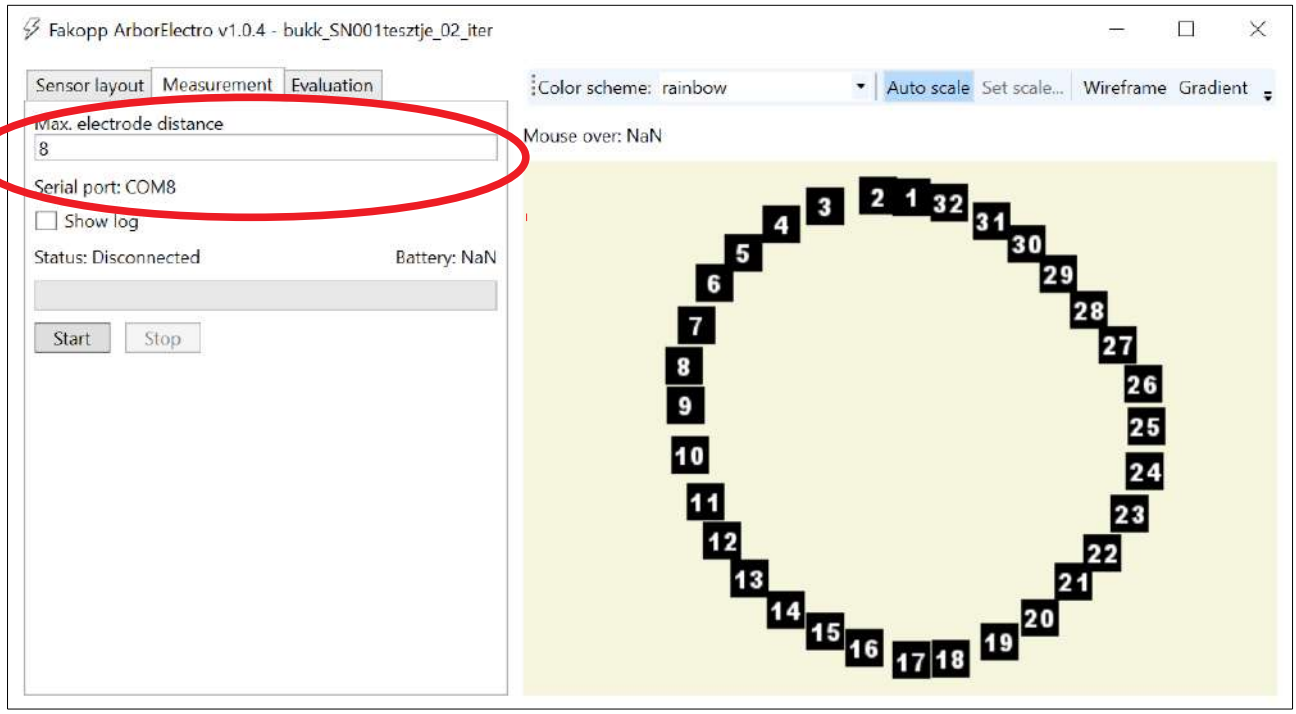
For Selecting the COM port, please go to “Options...” on Sensor layout tab. (More information *Software / Sensor Layout* chapter)

Start the caliper with the “Star” button on Sensor Layout tab (it will turn into “Stop”). Push the yellow button on the caliper a few times. When the connection is established, a green sign appears next to the “Stop” button. If speakers are on the program also tells you which distance should be measured.

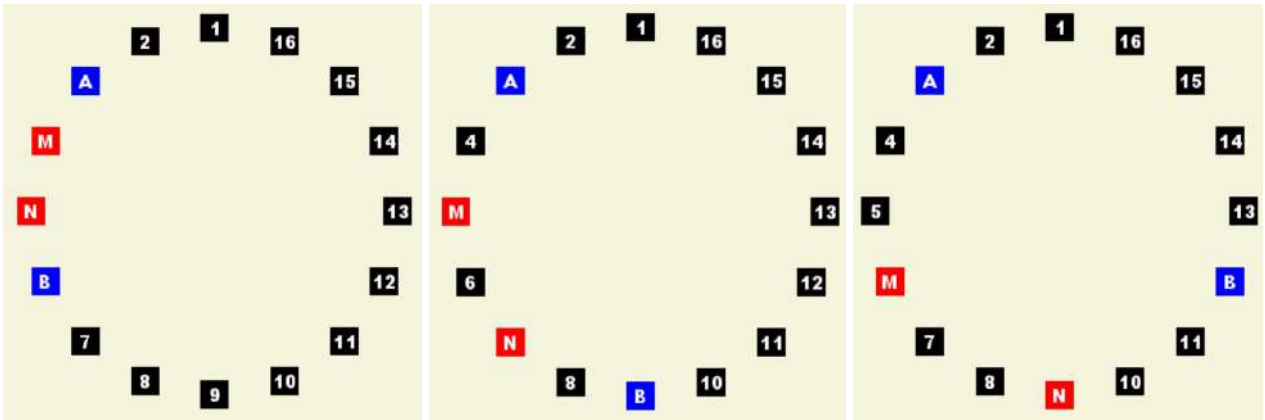


Measurement

When you are ready with the sensor layout data, you can go on to the Measurement tab. Here you can decide about the maximal electrode distance, start the measurement itself and follow the measuring process.

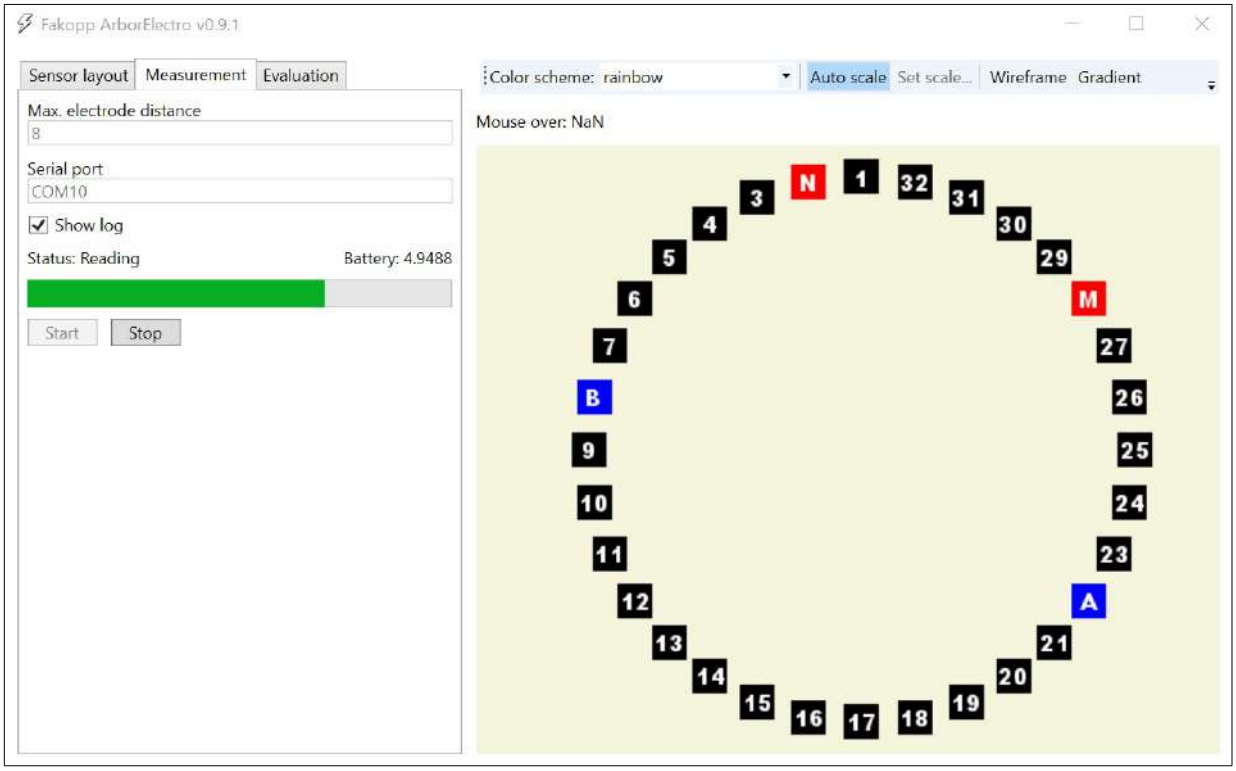


Max electrode distance is the biggest gap between two electrodes which has a role A, B, M or N.
It is recommended to keep the maximal electrode distance offered by the program. Results can become unreliable if maximal electrode distance is too low (according to the number of used electrodes).



Electrode distance is one (left), two (middle) and three (right)

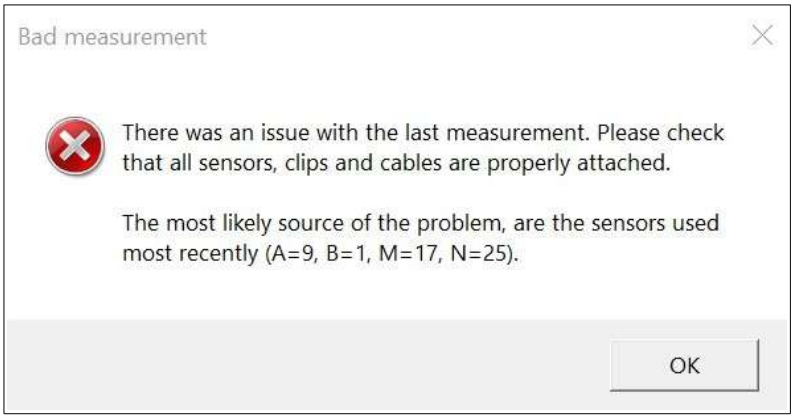
You can start measuring with the Start button. If the resistivity meter is charged, turned on and the connection between the device and the computer is working the “Status:” becomes “Reading”. The program sets voltage and current sensitivity for the actual measurement (depending on the trunks parameters). It take a short time before the start of the measurement itself.



During the measurement you can follow how the roles of the electrodes are changing. A green status bar provides information about the progress of the measurement. It is possible to stop the measurement with pushing “Stop” button but in this case the previously measured data will be lost.

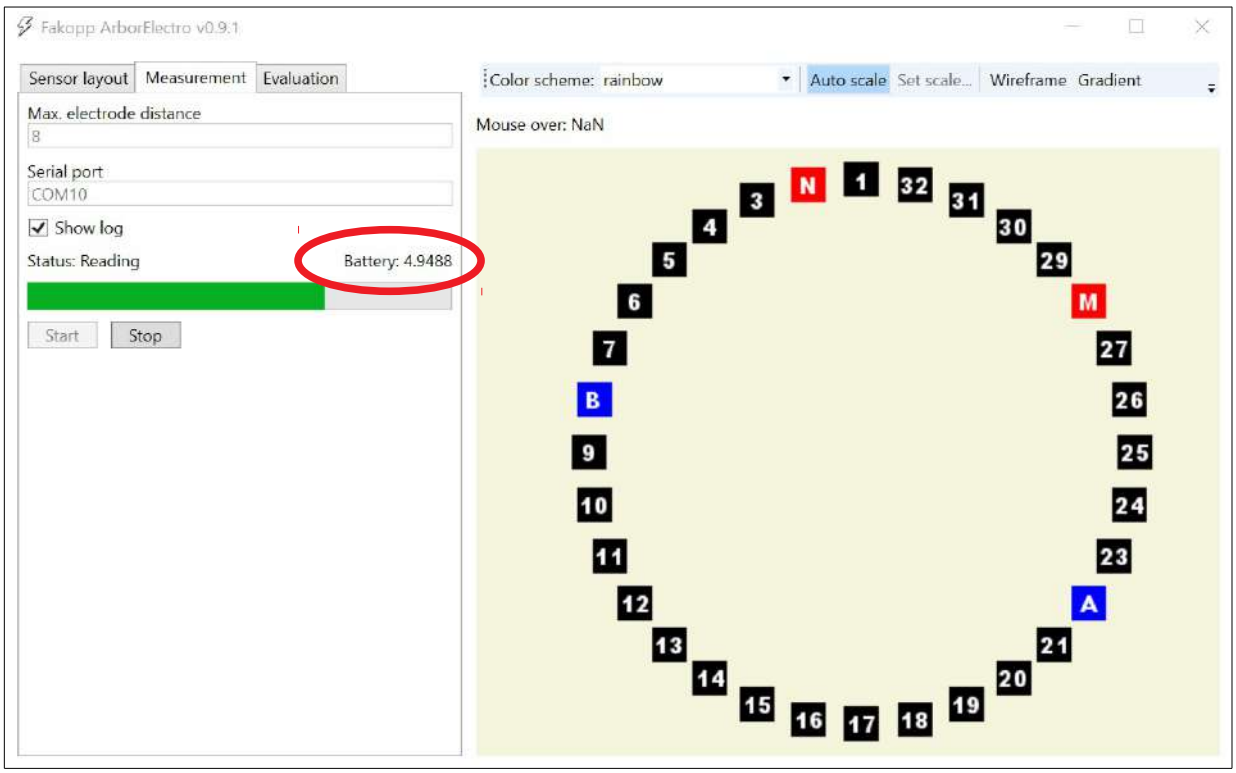
When the measurement is done, the progress bar turns back to gray. The data are collected, it is possible to go on to the evaluation steps.

The measure automatically stops with the following error message if the measured resistivity data is impossible (it means that not all the cables and electrodes are in there right place and/or deep enough to be coupled well to the wood).



In this case the measurement is stopped and no measured data is saved. It is recommended to start the checking with the electrodes and clips mentioned in the error message and their neighbours.

During the measurement you can also check the state of the battery

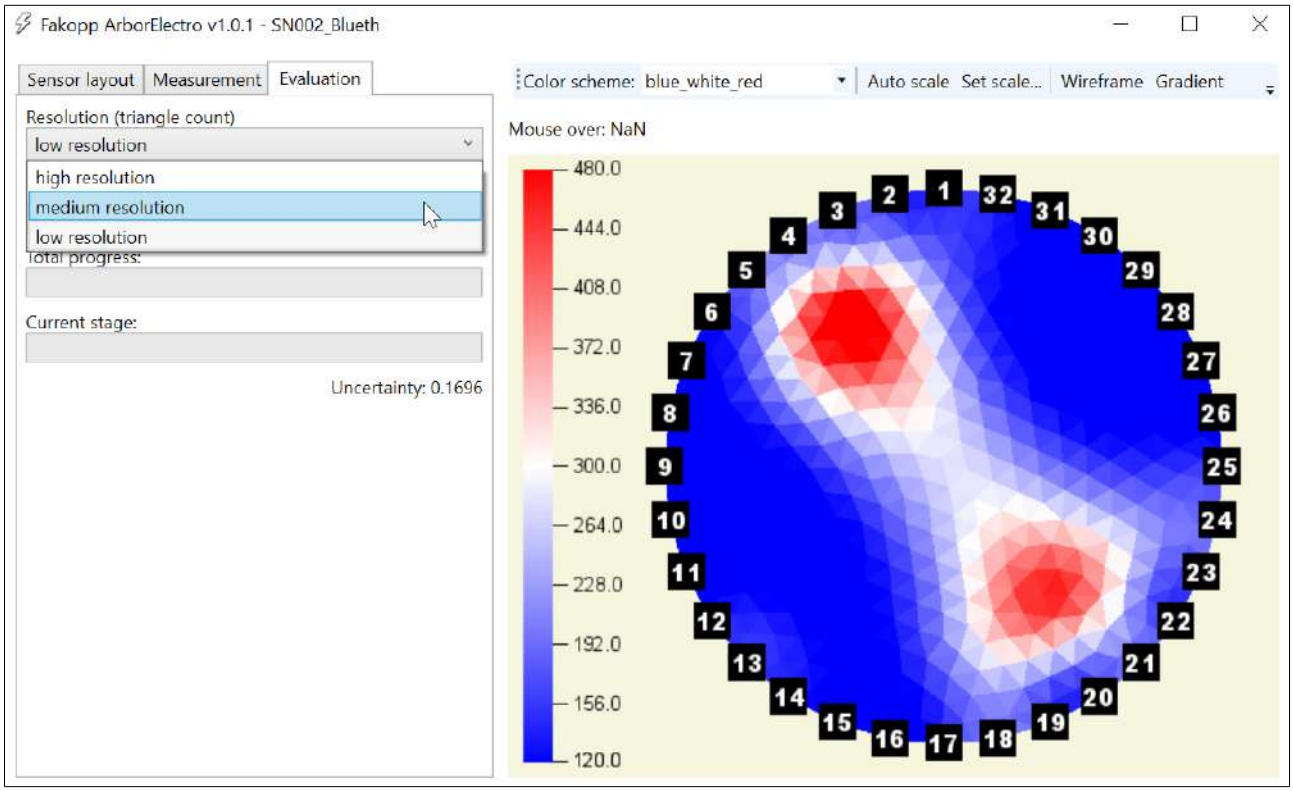


If the voltage output is under 4.94V it is recommended to charge the device. The current measurement can be finished and saved. But it is not recommended to start another one. The program sends you an error message in this case as well.



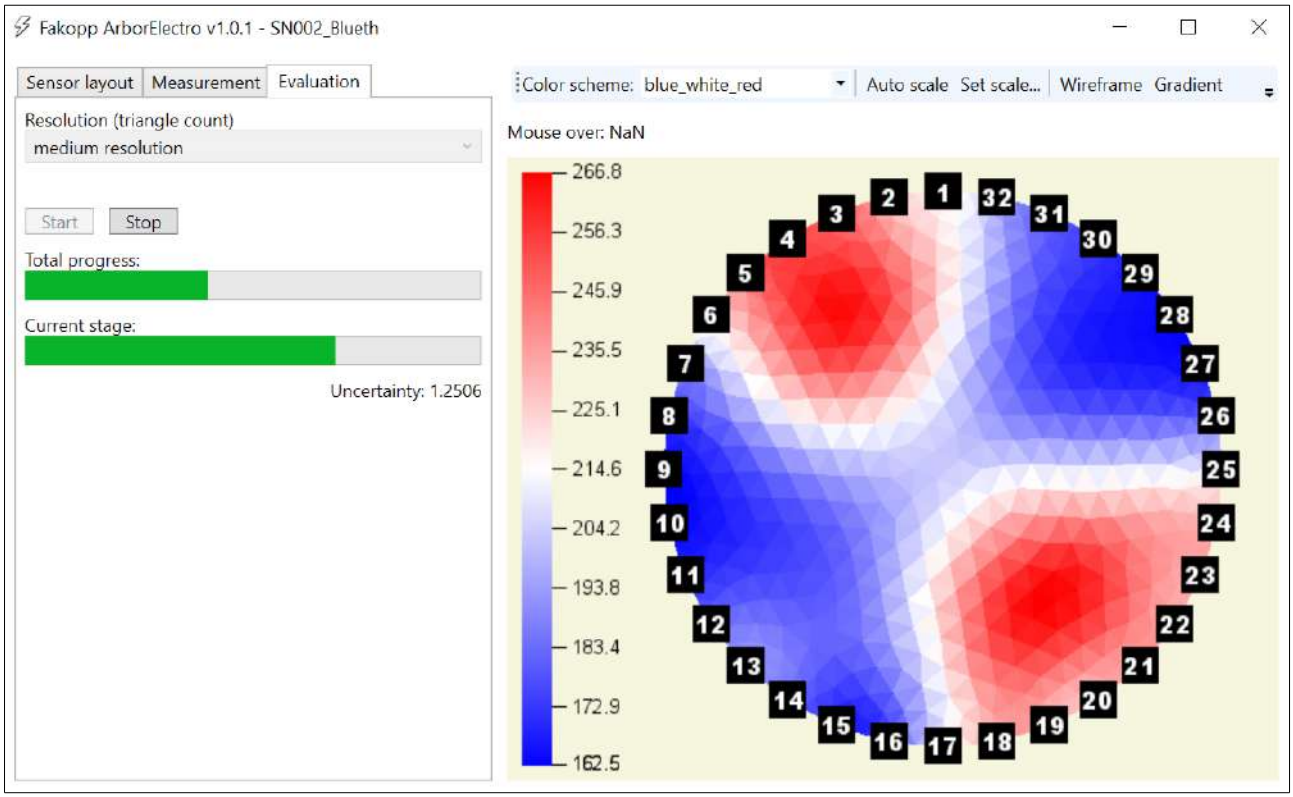
Evaluation

For evaluating the data you can choose “Resolution”. There are “low”, “medium” and “high” resolutions. The “low” resolution means about triangles 900 if you measured with 32 electrodes. (With less electrodes the triangles used for evaluation are less as well.)

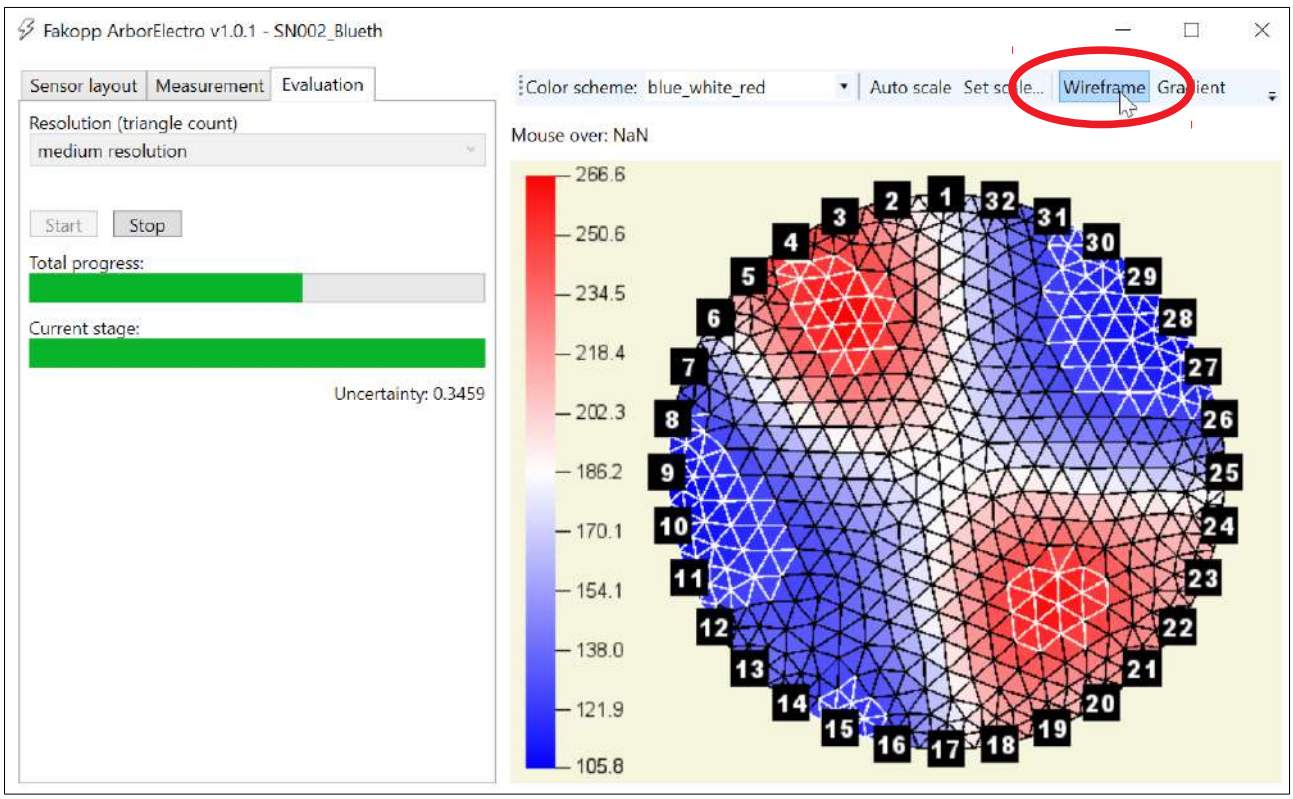


Note that if irregular geometry was used, the first step of the evaluation, the triangulation can last for several minutes. Please be patient and do not close the program. Depending on the number of the used electrodes, the chosen resolution and your computer the whole process can last for 50 minutes or even more.

For the evaluation push “Start”. You can follow the progress with the progress bars.

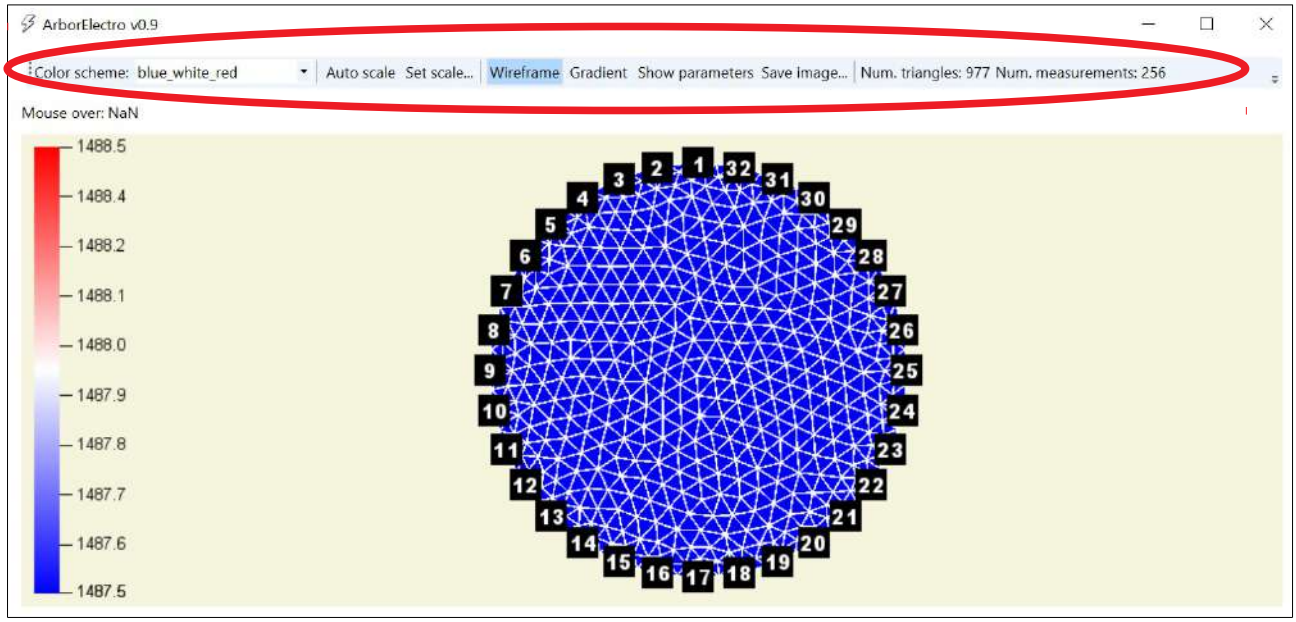


If you want to check the triangles, you can use the “wireframe” option to see the edges. (About this option please read *Software / Menu*.)

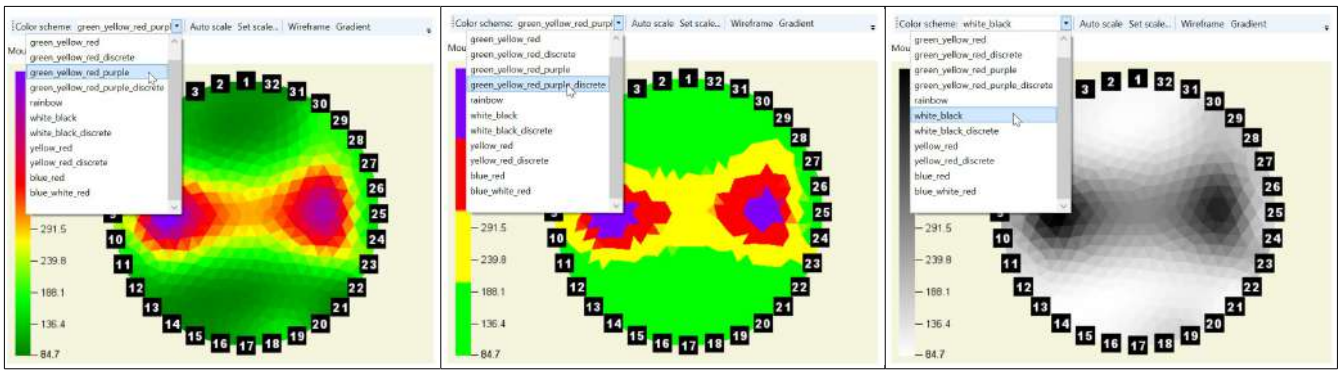


Menu

The program menu contains additional settings and some information as well. From left to right, the options are changing color scheme, using auto scale or not, display wire frame, use of gradients instead of separated triangles, showing parameters (on the left) or not and saving image of the tomogram. The displayed information are the number of triangles and the number of measurements.

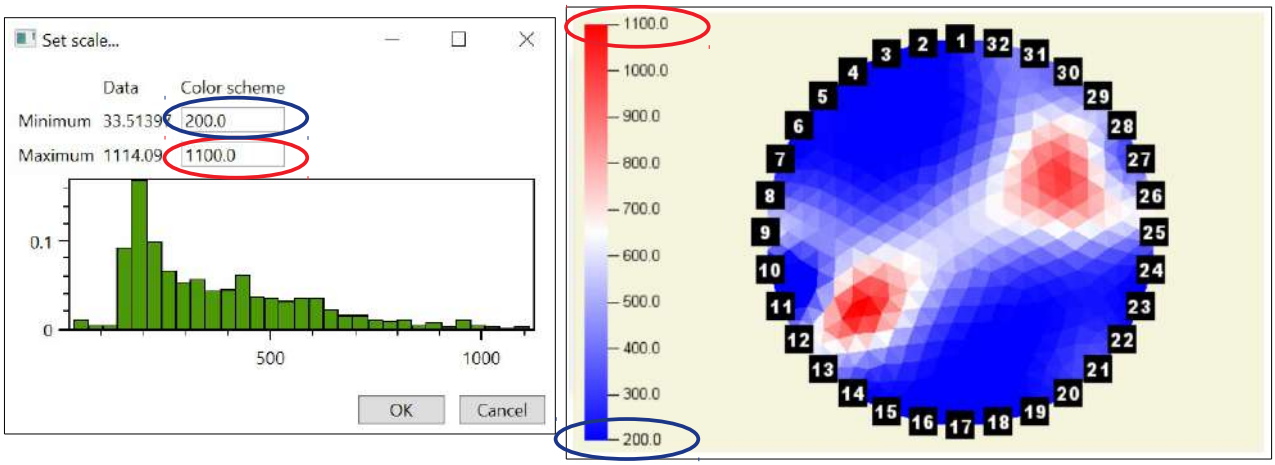


For visualization you can use different color schemes, discrete and continuous ones as well.

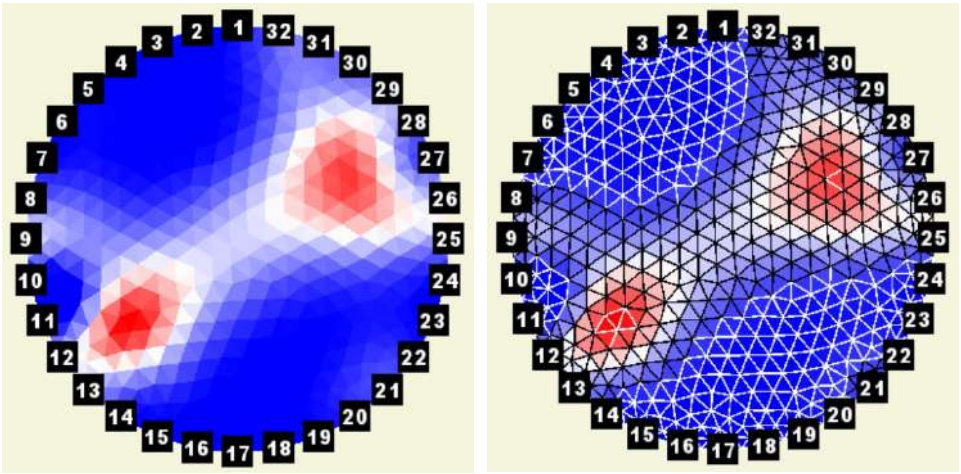


If auto scale is turned on, the scale's minimum is the lowest measured data while the maximum is the highest one. Using set scale helps to focus onto a resistivity range and highlight smaller changes. (You can use "Set scale" only if "Auto scale" is turned off.)

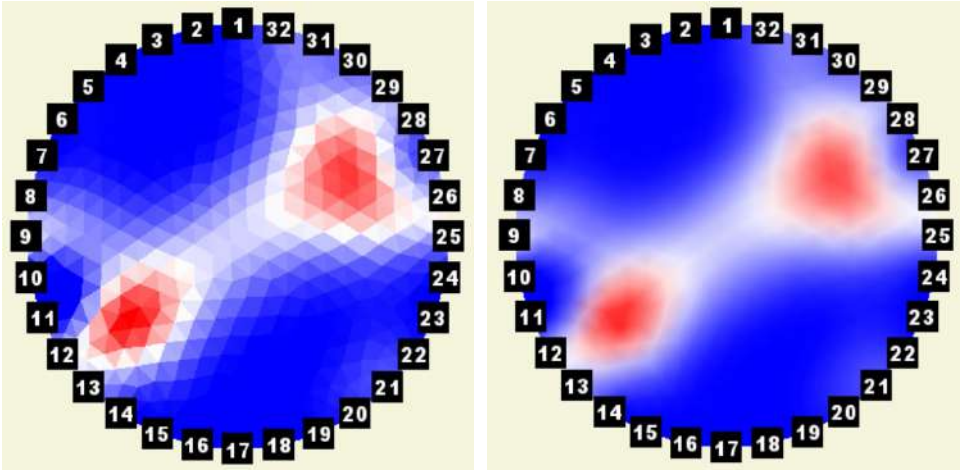
A new window appears when “Set scale” is clicked. Here you can check the measured and actual minimum and maximum. The histogram of the data is displayed as well.



“Wireframe” sets or eliminates wire frames.



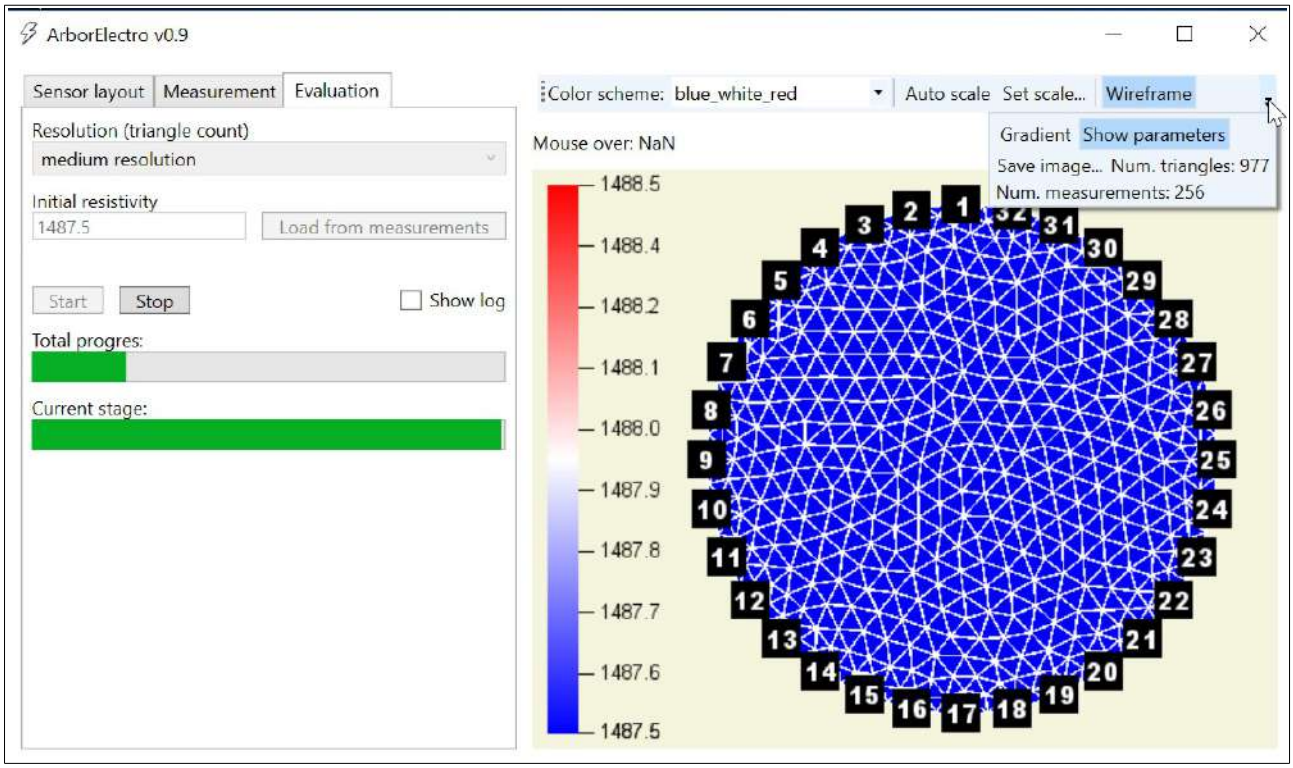
“Gradient” smooths the edges of the triangles.



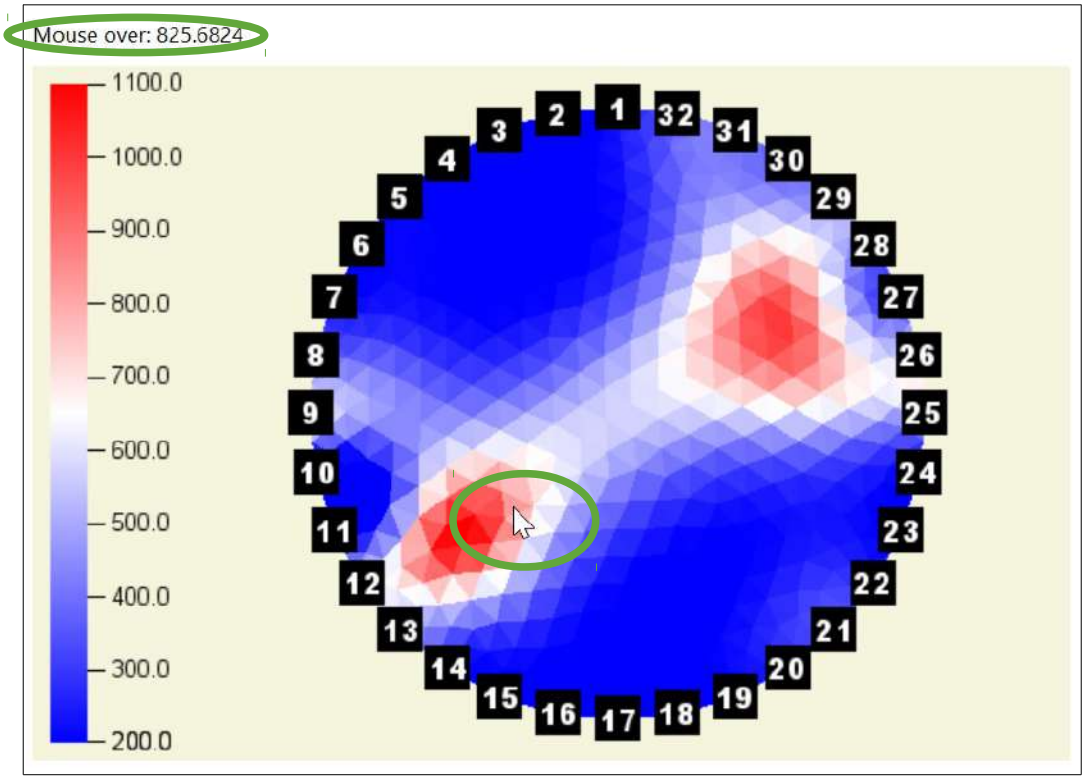
“Show parameters” displays the menu on the left, or hides it.

Push “Save image…” if you need an image of the actual resistivity map as you can see it in the window of the program. Note that only the image will be saved in this case not the data.

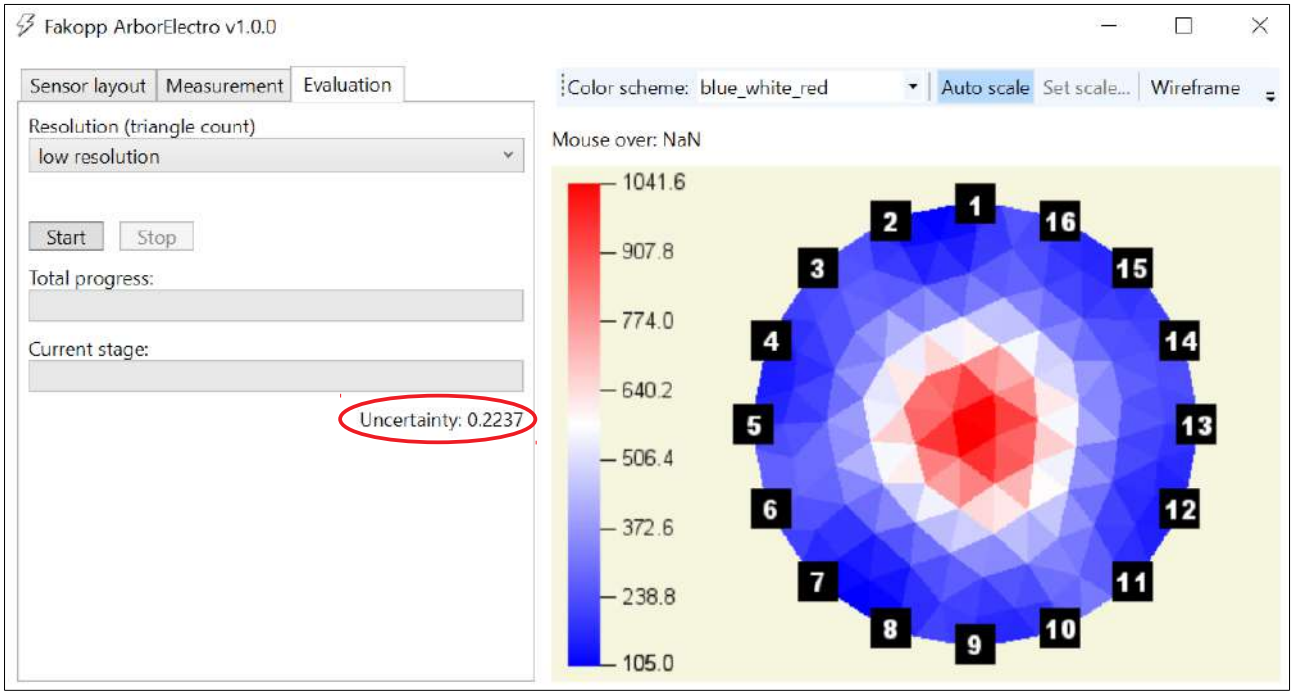
If the program window is not enough wide to show the whole menu, you can use the arrow in the right corner to see all tabs.



After the evaluation you can check the calculated resistivity values by moving the mouse over the triangle as well.



Uncertainty gives you information about the iteration's certainty. Do not trust the results if uncertainty is above 1.0.



Operation Guide

Charging

After a few hours of usage, before the first measurement, or if the green led is flashing, please charge the resistivity meter. The whole charging can last up to 4 hours with fast charger of up to 15 hours with not fast charger. The device can operate up to about 15 hours with full charge if it is connected to the computer by cable. In case of using Bluetooth the operation time reduces.

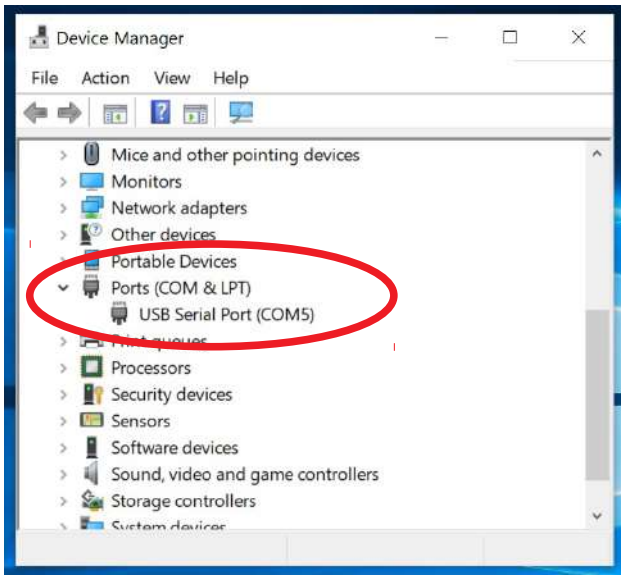
Be sure that the resistivity meter is turned off. If it is not, turn it off with the button on the front. Connect the LEMO-USB charging cable to the „Charging" input. Please take care to not break the cable. (You may charge the resistivity meter on the top of it's case or upside down, try not breaking the cable.)

During charging the led on the front lights in red. At the end of the charging disconnect the LEMO-USB charging cable. It is not possible to measure during charging.

First connection to a computer with cable

Turn on the resistivity meter. Connect the LEMO-USB connection cable to the „UBS" input on the front of the device. Connect the LEMO-USB connection cable to the computer as well. Please wait until your operation system recognizes the connection. Please install the needed drivers. This step can last for 30 minutes (or even more) depending on your operation system, computer and web connection. Please be patient and let your system find and install the drivers. Later the computer will be able to recognize the resistivity meter in a few seconds.

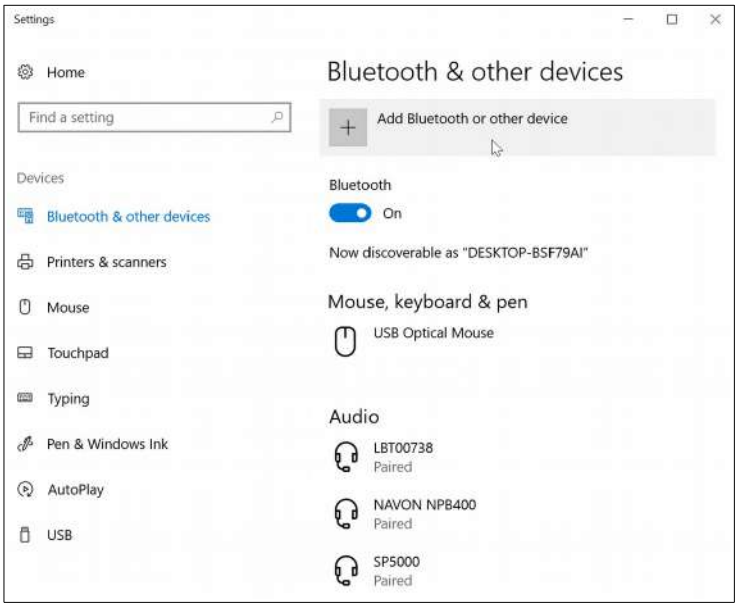
When both the USB Serial Converter and the USB Serial Port (COM _) are installed, please check the Device Manager and read the number of the COM port eg. COM5. The number of the COM port will be asked by the ArborElectro program. (The device usually connects to the same COM port as well. However checking the number of the COM port is recommended.)



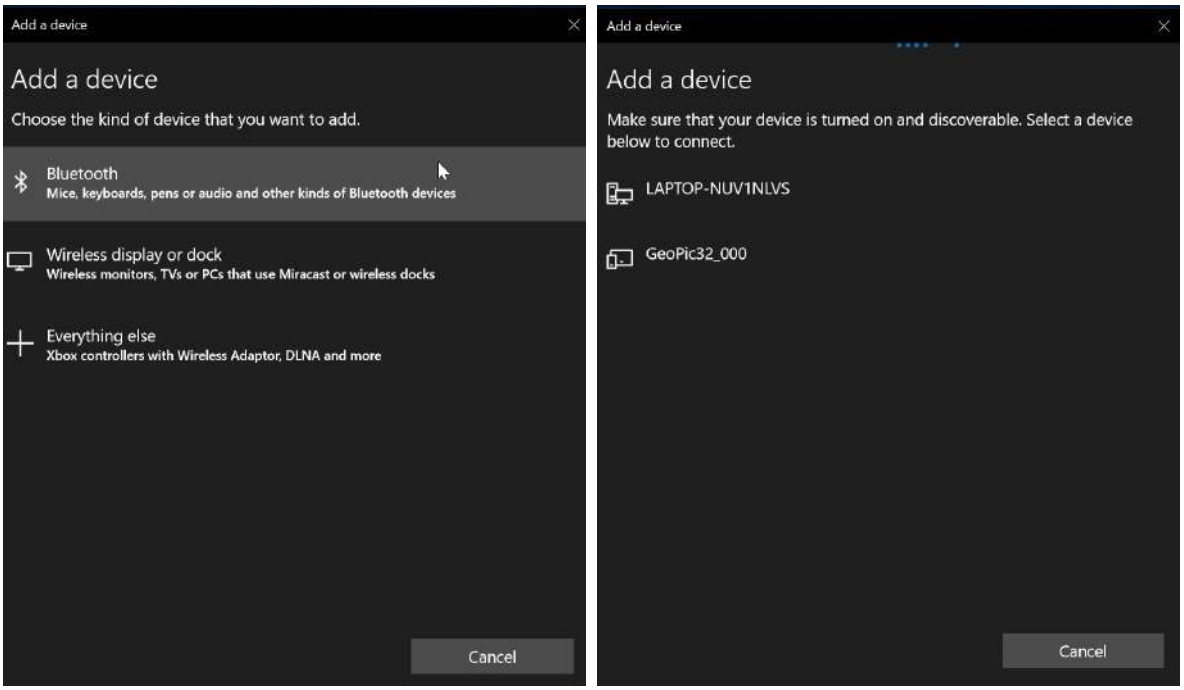
The device manager. Look for "Ports (COM & LPT)"

First connection to a computer via Bluetooth

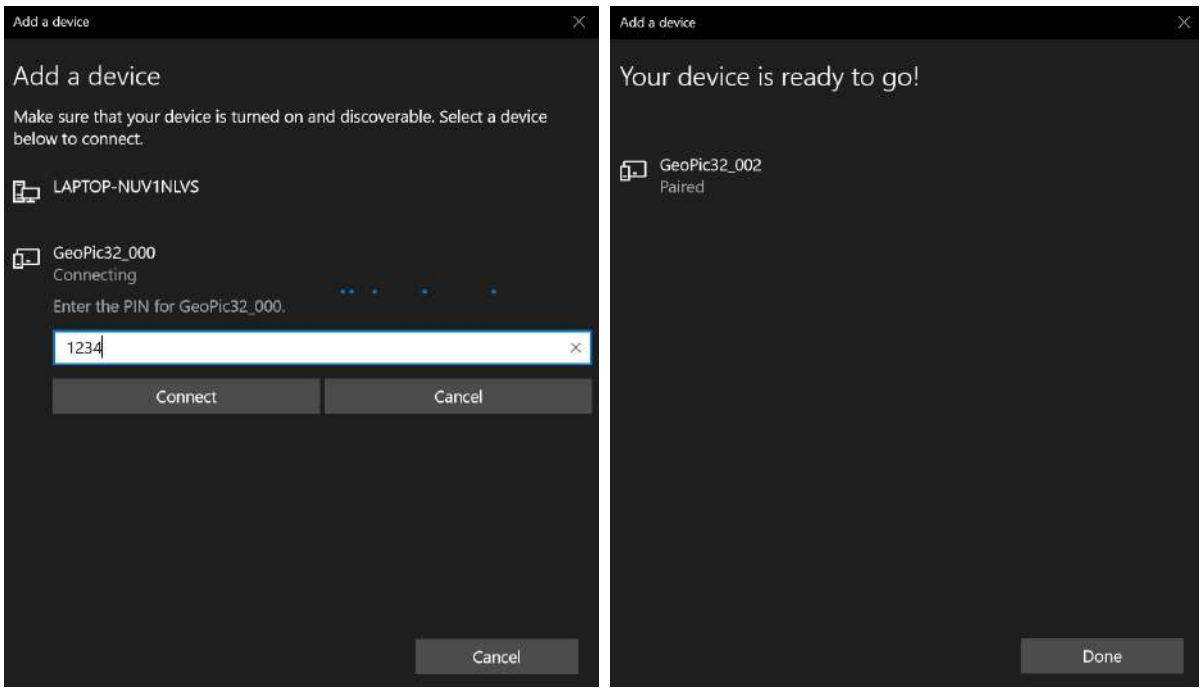
Turn on the resistivity meter. Open “Bluetooth & other devices”. Push “Add Bluetooth or other device”.



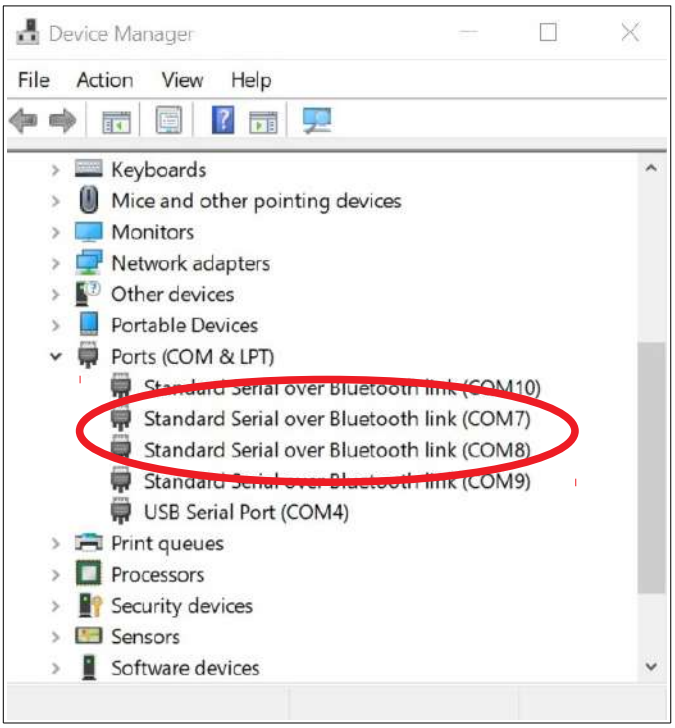
On the following screen, choose the option “Bluetooth”. The computer will recognize the available Bluetooth devices. Please be patient, this step may need a few minutes. Choose GeoPic32_xxx.



Enter 1234 to the password field.

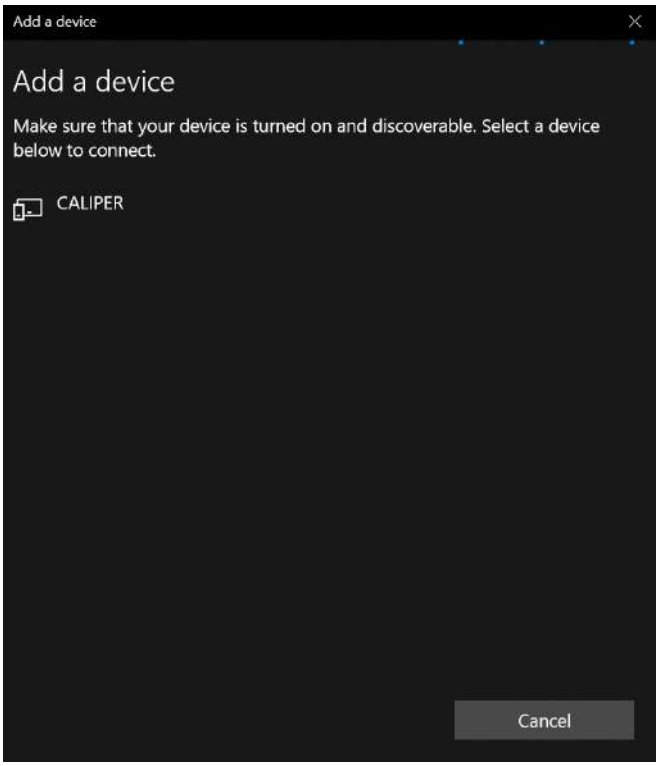


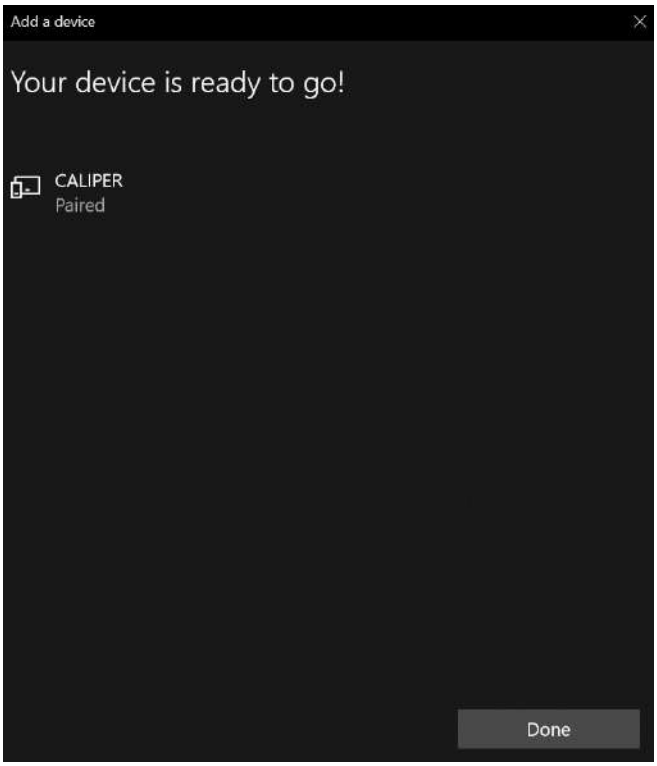
After pairing the resistivity meter, please check the COM ports at the “Device manager”.



There may be 2 new ports. One of them is a sending port, the other is a receiving one. You will have to use the receiving one. The number of the new ports depend on your system. The number of the COM port will be asked by the ArborElectro program. (The device usually connects to the same COM port as well. However checking the number of the COM port is recommended.)

Adding a Bluetooth Caliper to your system is similar to adding the Resistivity Meter. First you should turn on the caliper. Then open “Bluetooth & other devices” and push “Add Bluetooth or other device”.





There is no password for the caliper.
When the progress finishes the caliper is ready. Note that when you don’t use the caliper it shouts down after 100-120 secs (to save battery).

Measurements

Select a tree and a layer which you are going to measure. It is not recommended to measure too close to the ground level.

1. Install the resistivity meter onto the tree. Select a point for a screw. It should be above or under the layer selected for the measurement. Drive the screw into the tree in an angle about 45°. It will have to hold the resistivity meter.





2. Fix the tape measure around the trunk at the selected layer. If the trunk in the selected layer is a circle or ellipse, you will be able use the needle positions calculated by the software.





3. Start the program on the computer. Push the button “New” (to be sure your measurement will not be bothered by data from previous measurements). Decide if you are going to use 16, 24 or 32 electrodes. Select Sensor count and Sensor layout shape in the program.

a) Circle

Measure and type in the circumference.
Push the button “Show distances...”
The program calculates the positions of the electrodes.

b) Ellipse

Measure and type in the vertical and horizontal axis, and the circumference.
Push the button “Show distances...”
The program calculates the positions of the electrodes.

c) Irregular

Fist you have to put the electrodes onto the tree (look for the general advice in the next sub chapter) then the distances requested by the program should be registered. The program calculates the shape and makes a diagram onto the right side with the electrodes.

Please add “Penetration depth” (the depth of penetration of the electrodes in centimeters) and “Bark thickness” data (the estimated thickness of the bark in centimeters).

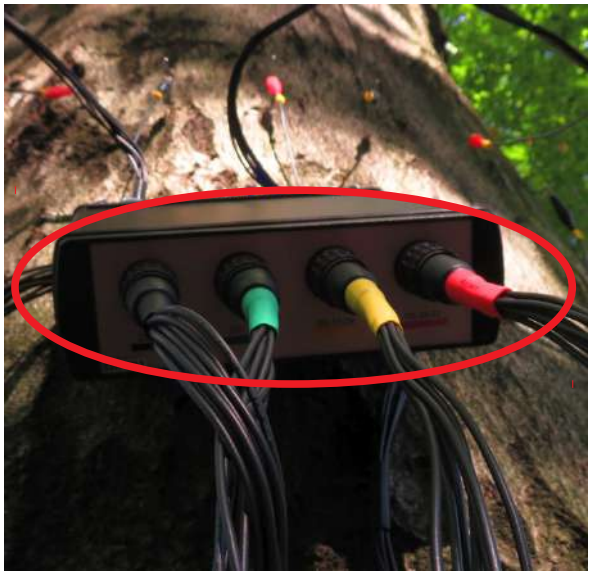
4. If the trunk’s shape is circular or elliptic the program calculates the proper positions of the electrodes. Place the electrodes onto the tree at these positions. The electrodes should be perpendicular to the bark. Use the tape measure to find the positions and hammer the needles through the bark into the wood. As the bark is non-conductor be sure that the electrodes went through and the signal can penetrate into the wood material.



Take care of yourself, your hands, finger and toes.

Remove the tape measure.

5. Connect the first electrode connection cables' main terminal to the back of the resistivity meter. The crocodile clips are numbered from 1 to 8 on this cable. Look for "Ch 1-8" input on the resistivity meter. The main end of the connection cable is asymmetric. Connect it to the resistivity meter with regarding the shape and fix the connection. Take care of connecting the right cable to the proper channels.



Connect the crocodile clips onto the electrodes. Start with the first electrode connection cable. Start with number 1 and go one by one till 8. The first clip is black. Please place it close to the resistivity meter. Use exactly one clip for one electrode. Do not skip an electrode or change the order.

Go on with connecting the electrodes. (Odd ones are black, even ones are red.) Use the second electrode connection cable with clips 9 to 16 similarly. Use the third and fourth electrode connection cables if they are needed.



Be sure that the crocodile clips are on the needles, the needle is between the "teeth" and not under them.

6. Check the followings before starting the measurement:
- the computer is turned on
- the data on “Sensor layout” tab are correct
- the electrodes are on the tree at proper position with clips on each of them
- the electrode connection cables are connected to the resistivity meter
- the tape measure is NOT on the tree

Turn on the resistivity meter. The led should give a continuous green light. (If the light is flashing or there is no light at all, please charge the resistivity meter.)



Choose the number of the COM port which is used by the device in “Options...”. Go to the “Measurement” tab select sensor layout and maximal electrode distance. Start the measurement. The blue led of the Bluetooth will light only when data is being sent to the computer. For more information please read *Software / Measurement* chapter.

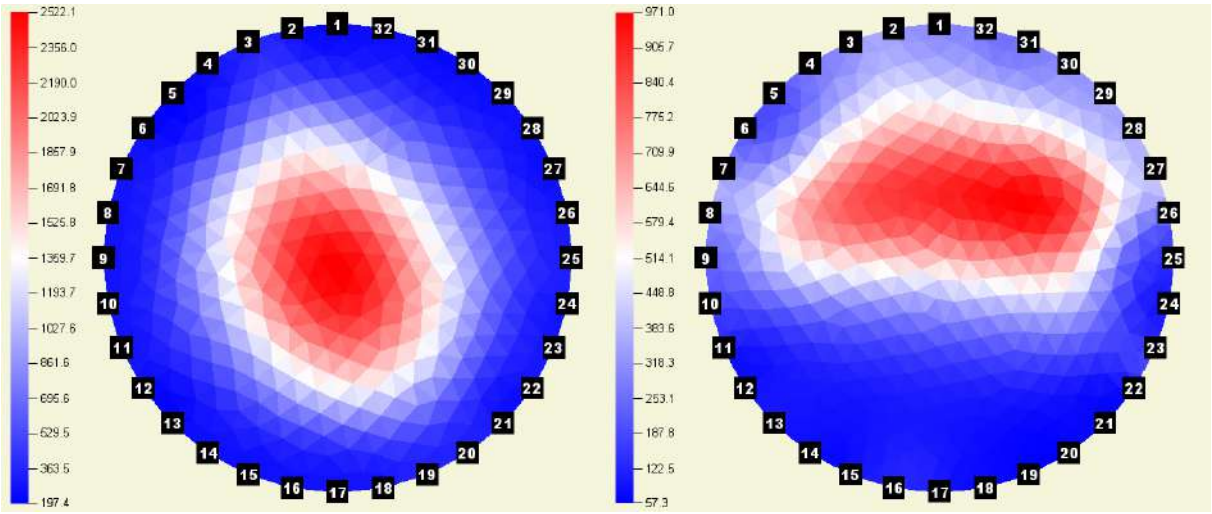
Measuring irregular shape

Advice
Try to put the electrodes onto the tree with a constant distance from each other.
Use a (electric) caliper to measure the distances of the electrodes from the first and 9th / 13th / 17th electrodes.

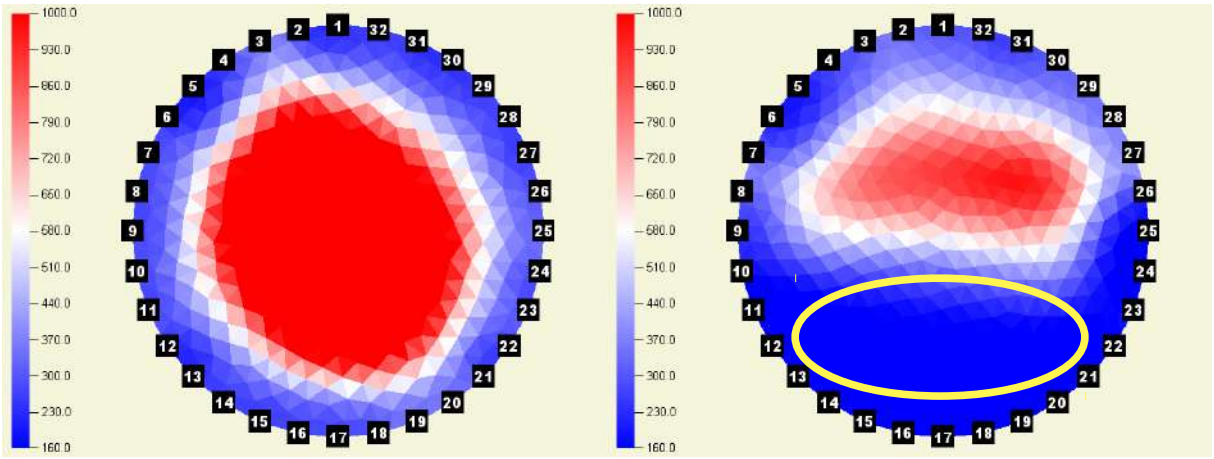
Interpreting the tomograms

Healthy trees usually do not show homogeneous resistivity. In-homogeneity depends on the specie as well.

Some examples for healthy and actively attacked trees are following. In these tomograms blue refers to low resistivity, high conductivity while red refers to high resistivity and low conductivity. Low resistivity can refer to active fungi.

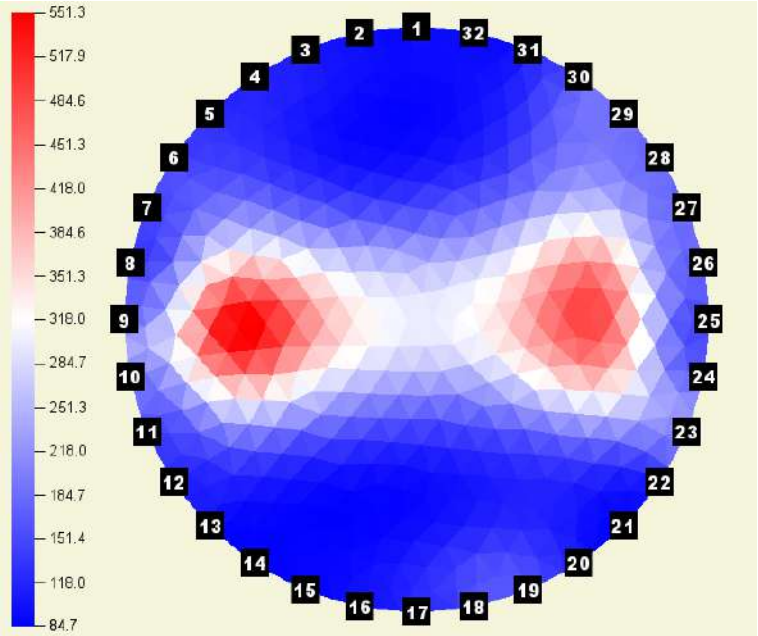


Healthy spruce (left), attacked spruce (right)

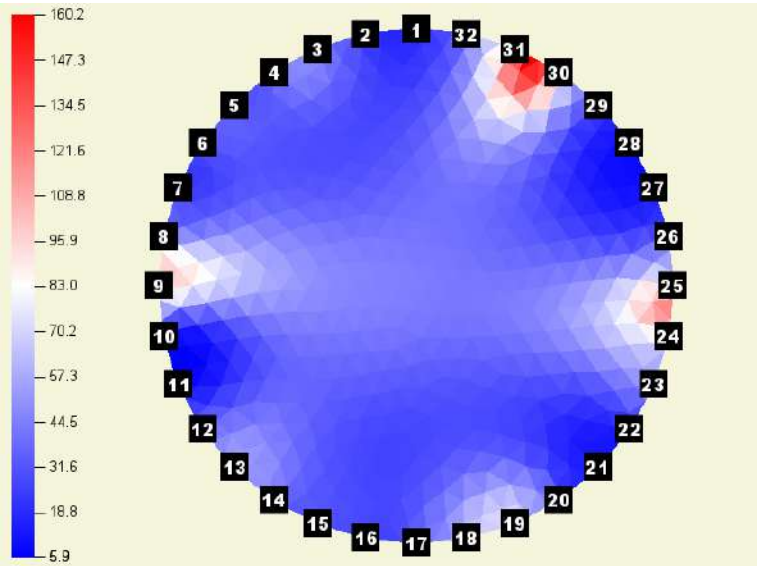


Healthy spruce (left), attacked spruce (right) after synchronization of the scales

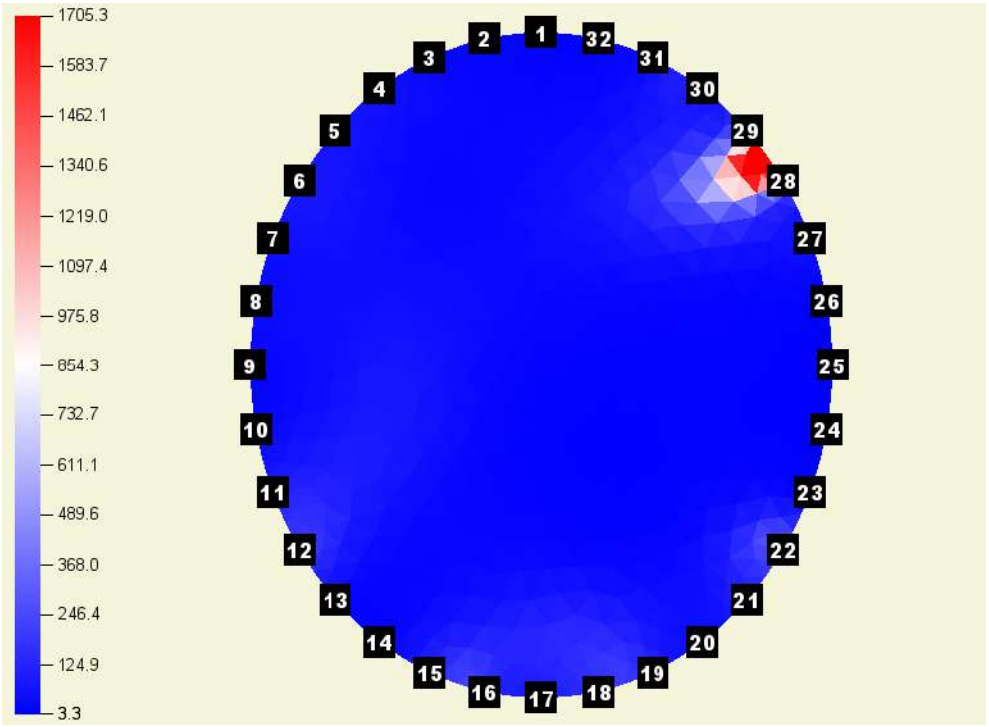
The difference between the healthy and attacked states is more highlighted if the scales are the same. The blue region refers to low resistivity and high conductivity. The blue region on the image on the right refers to fungal activity (highlighted with the yellow ellipse).



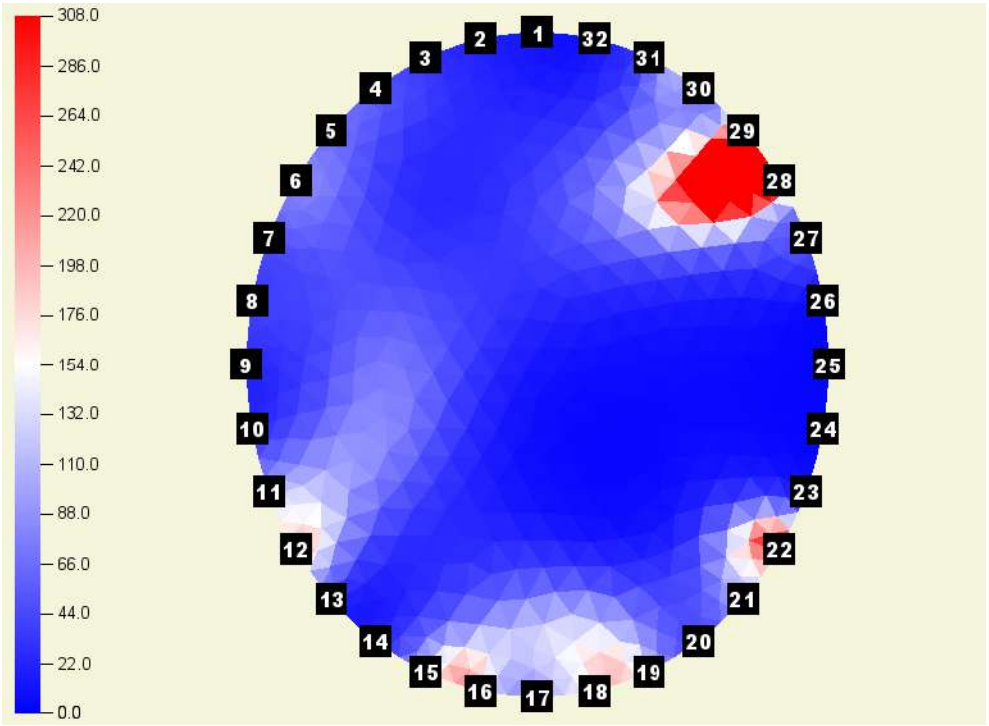
Healthy beech



Healthy redwood with dead knots



Healthy chestnut with wound reaction (around electrodes 28 and 29) with automatic scale



Healthy chestnut with wound reaction (around electrodes 28 and 29) with a scale set to from 0 to 308 to see more details (dead knots)

Advice and safety regulations

Do not touch the tree during measurements.

Remove other sensors from the tree / bark before starting resistivity measurement.

Take care of your fingers, toes,... placing the electrodes onto the tree and prepare for the force and loss of balance may happen during removing the electrodes.

Do not start acoustic and resistivity measurements at the same time on the same tree.

If you expect to measure trees with elliptic or irregular trunk shape, it is recommended to bring a caliper as well.

Do not use curved or broken electrodes.

Do not use the resistivity meter if the temperature is below 0 °C / 32 °F or more than
40 °C / 100 °F.
Do not use the device in heavy storms, raining or in foggy conditions.

Charge the resistivity meter after the measurement.

Before measuring be sure that both the resistivity meter and the computer are well charged.

Bringing a folding table with yourself to the measurement is recommended for holding the computer.

This device is for measuring living trees. Do not use it for any other purpose.

Sterilize the electrodes / needles before measurements. It is possible to infect tree if a previously measured tree was infected.

Do not open the resistivity meter. If there is a problem with the device please contact us. Opening the resistivity meter cancels all guarantee.

The device includes sensitive parts as well, do not drop it, step onto it, put it under water.

The connection and changing cable are NOT similar. Do not replace them with each other. And take care always using the proper one.

Always save the data after the measurement.

Maintenance

Keep the device in a dry place in room temperature.

If you have to clean it please use a lightly wet towel.

If rosin got to the clips or the electrodes you can clean them with benzine. Take care of the handling of the chemical.

If any of the parts are broken please contact us.

It is recommended to switch off the device after measuring.

Do not break the cables and keep them coiled up to avoid tangle.

Guarantee

The guarantee last for one year from posting the device.

Appendix – Quick checklist for measurement

Is the ArborElectro program installed onto the computer?

Are the resistivity meter, the computer (and the caliper) charged?

Are the needles clean (sterilized)?

Check your case if every part of the device is inside.
(resistivity meter, cables, electrodes, hammer, remover tool, tape measure, screw and screwdriver)

After arriving to the proper tree and the layer is selected for measurement
- place the tape measure onto the tree at the layer (you can use one needle to fix the end of it)
- put on the needles
- remove the tape measure
- place the resistivity meter onto the tree (onto a screw)
- place the crocodile clips onto the needles and connect the cables to the resistivity meter
- turn the resistivity meter on
- measure with the program
- save your data
- turn of the resistivity meter
- if you have time run a low resolution iteration to check the tree’s conditions
- remove the cables, the resistivity meter form the tree
- remove the needles with the remover tool
- clean and pack everything back to the case