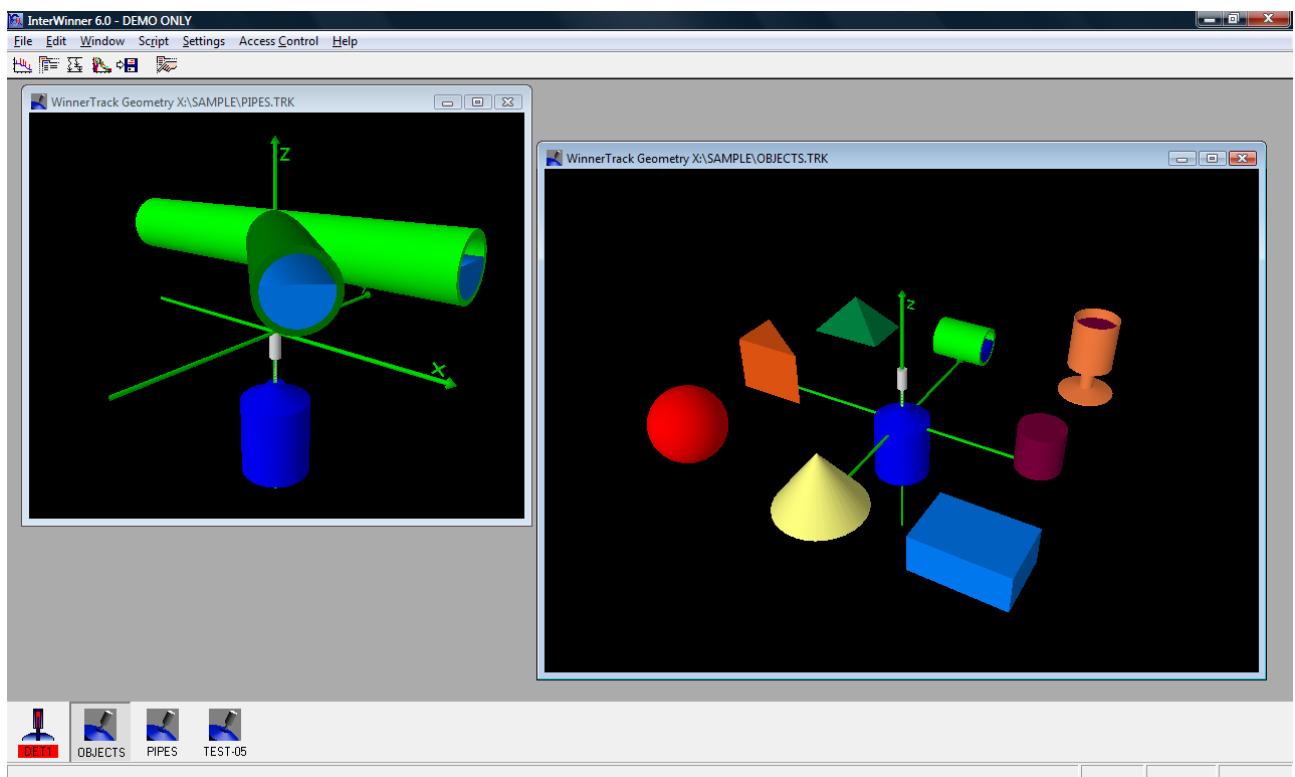


WinnerTrack



Manual

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1 Introduction

To determine which radioactive isotopes are contained in a sample one commonly uses γ -spectroscopy. Doing so you measure the samples γ -rays with a pure germanium detector. The γ -radiation consists of photons that range in the energy scale between 30 and 6000 keV. It occurs during the radioactive decay, we may deal with α , β^+ , β^- -decay as well as with spontaneous fission, that excited atomic nucleus is created. For the most part they merge rather fast (some ns - μ s) to their ground level. The hereby liberated radiation is emitted as photons.

The γ -spectrometer determines how many photons of which energy level are emitted during the process. To analyze the so created γ -spectrum we need the Energy- and efficiency calibration. The energy calibration is linked to the detector and the adjustments of the applied electronics. It is easy enough determined in measuring beforehand a known source of radioactive nuclide.

More demanding is the determination of the efficiency calibration. It depends not only on the detector used, but also on the geometry and distance of the sample. To determine the efficiency calibration experimentally you need to examine a sample of known activity and nuclide composition that has the exact same geometry as your reading sample. In the case of a typical lab sample e.g. a Marinelli beaker that may not pose a problem. But if we talk In-Situ readings, barrels, tubes or similar, that can cause unsurmountable difficulties. Caused by sample size and screening effect of the used materials (steel, concrete) one needs big and barely manageable activities.

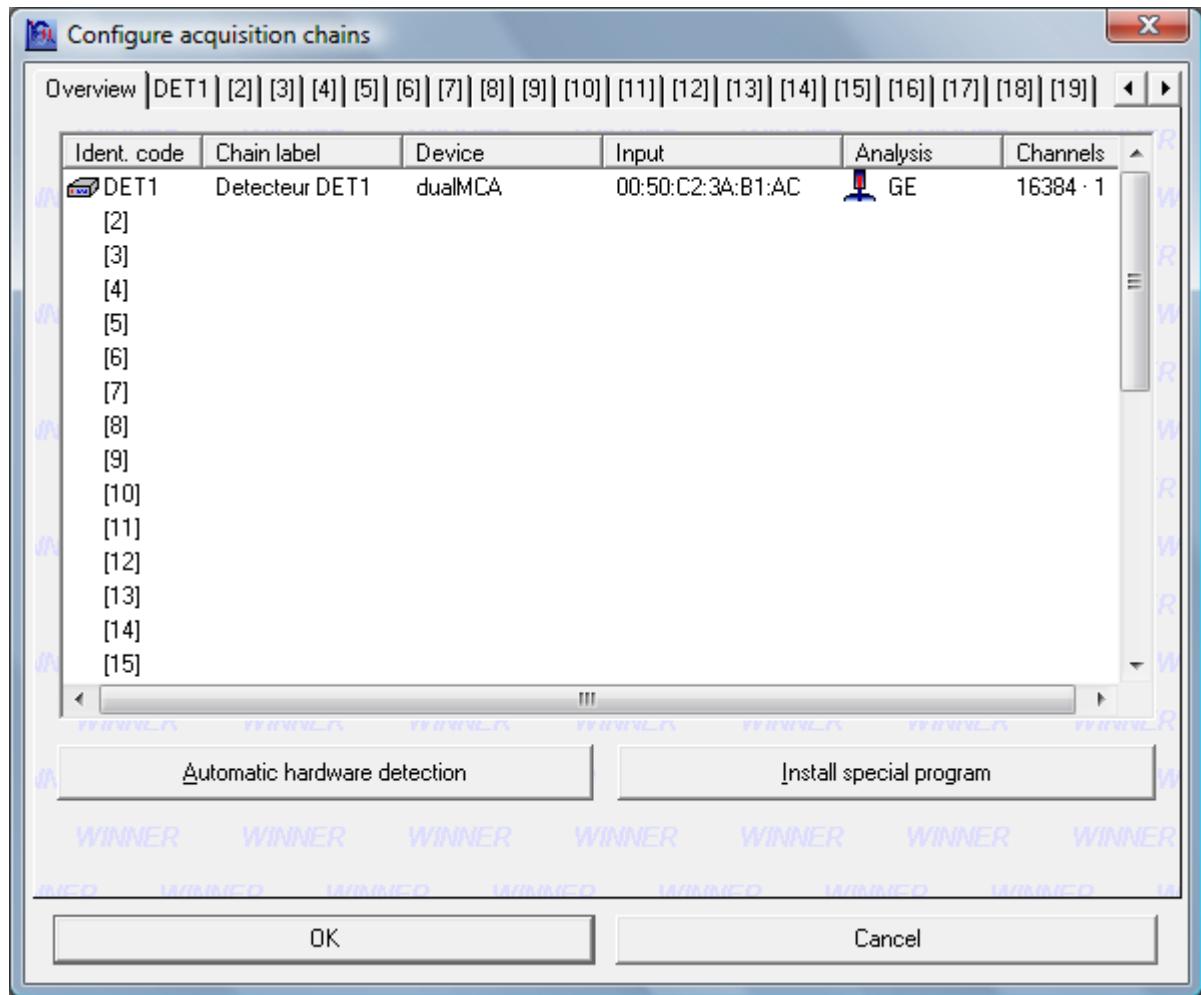
For applications such as these it is therefore highly recommended to calculate the efficiency calibration. That means to model in the computer composition and material of the sample as well as of the screening. Proceeding from the known detector properties it is now possible to determine the efficiency of any chosen sample setting.

The here presented software was created to be an efficient tool for exactly this specified purpose. Its handling is explained in the following.

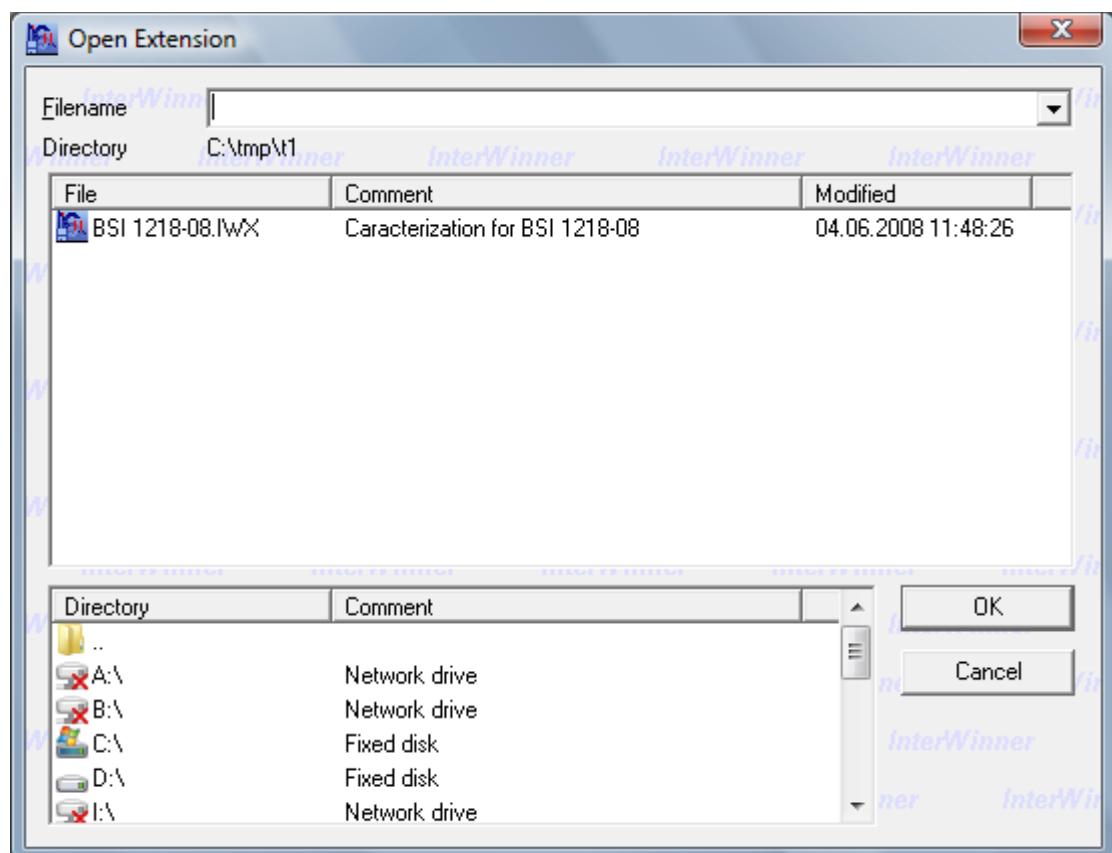
2 Installation

The WinnerTrack software itself installed automatically during the process of installing InterWinner provided that the option is activated in the dongle. Merely the characterization of the used detector needs to be installed as follows:

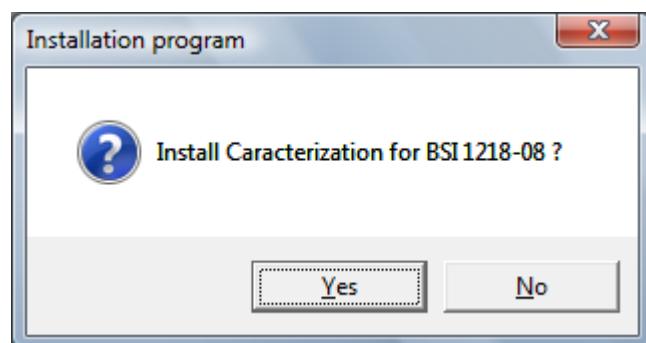
Start the InterWinner configuration software and press [Install special program].



Now select the file that contains the calibration.



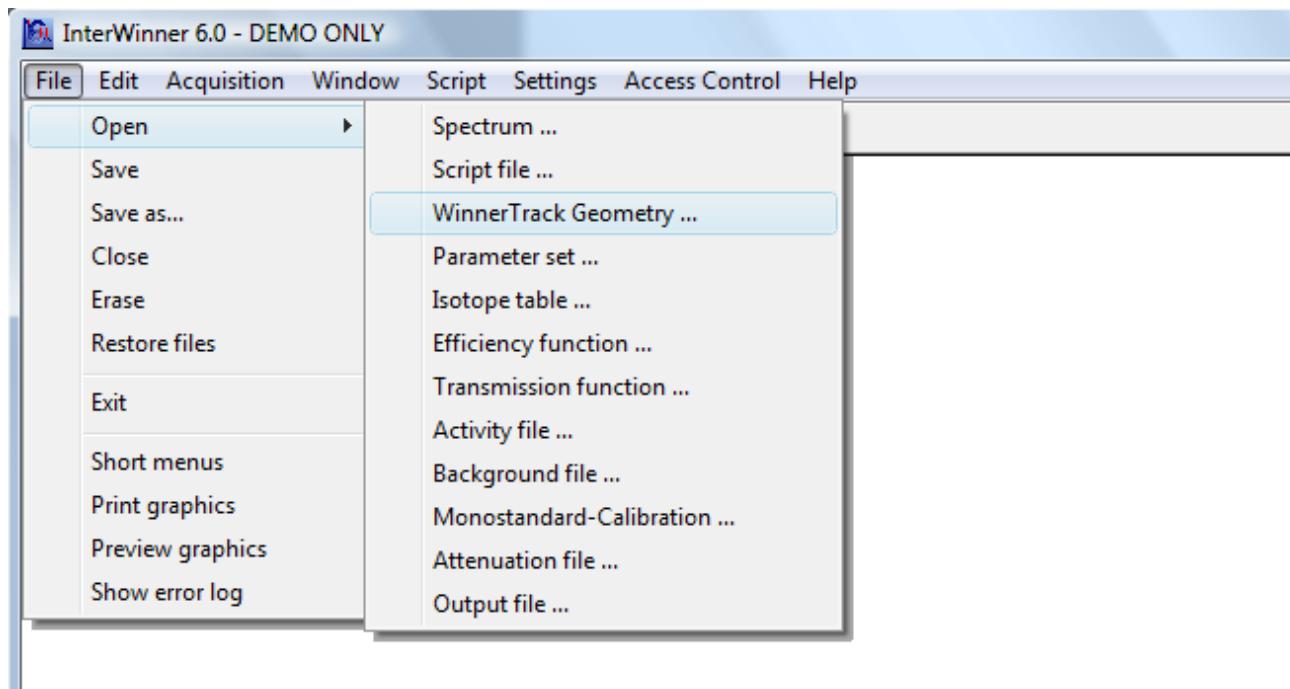
The software will ask for a confirmation and then install the files automatically.

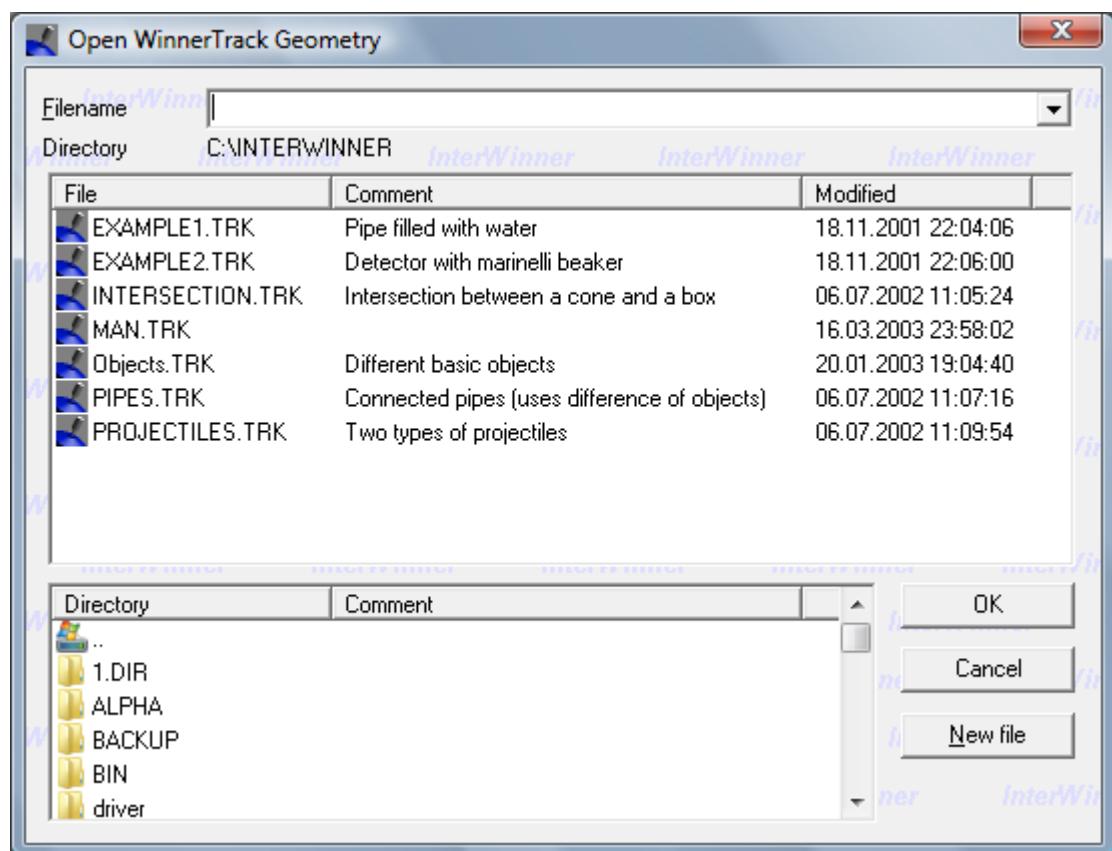


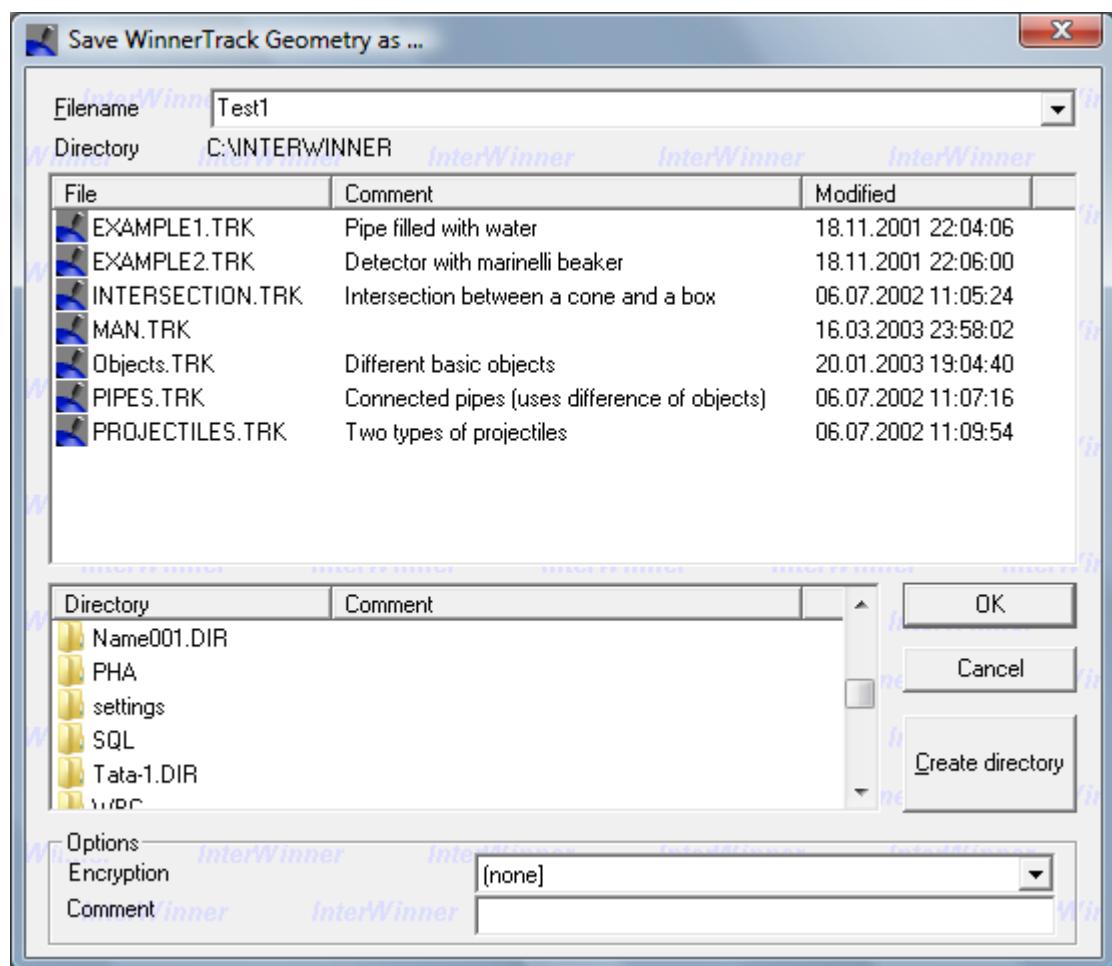
3 The user interface

WinnerTrack is integrated into InterWinner 6.00, therefore the operation is widely similar to that of other InterWinner modules. For instance, all numeric field permit entering not only numbers but also (Visual Basic) formulas (e.g. $50+100*\sin(30 * 3.1415926/180)$).

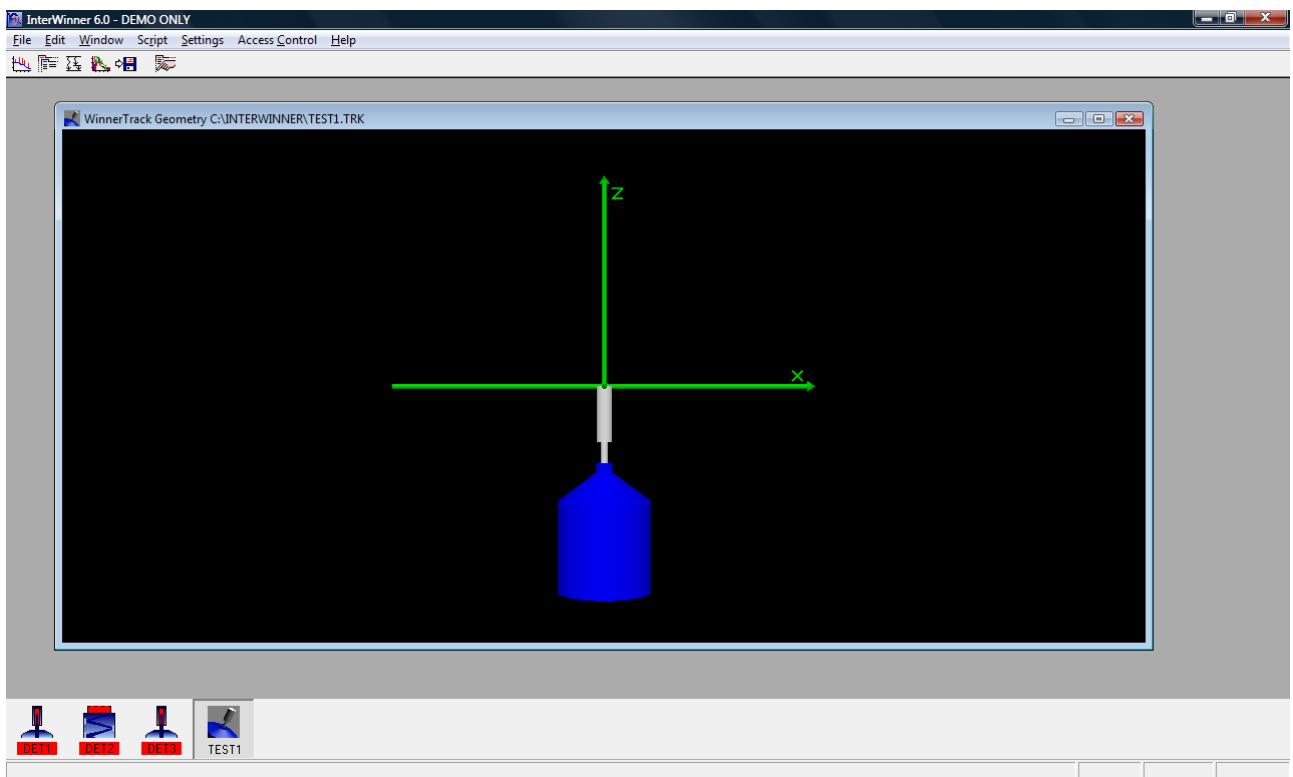
3.1 Loading or creating a geometry



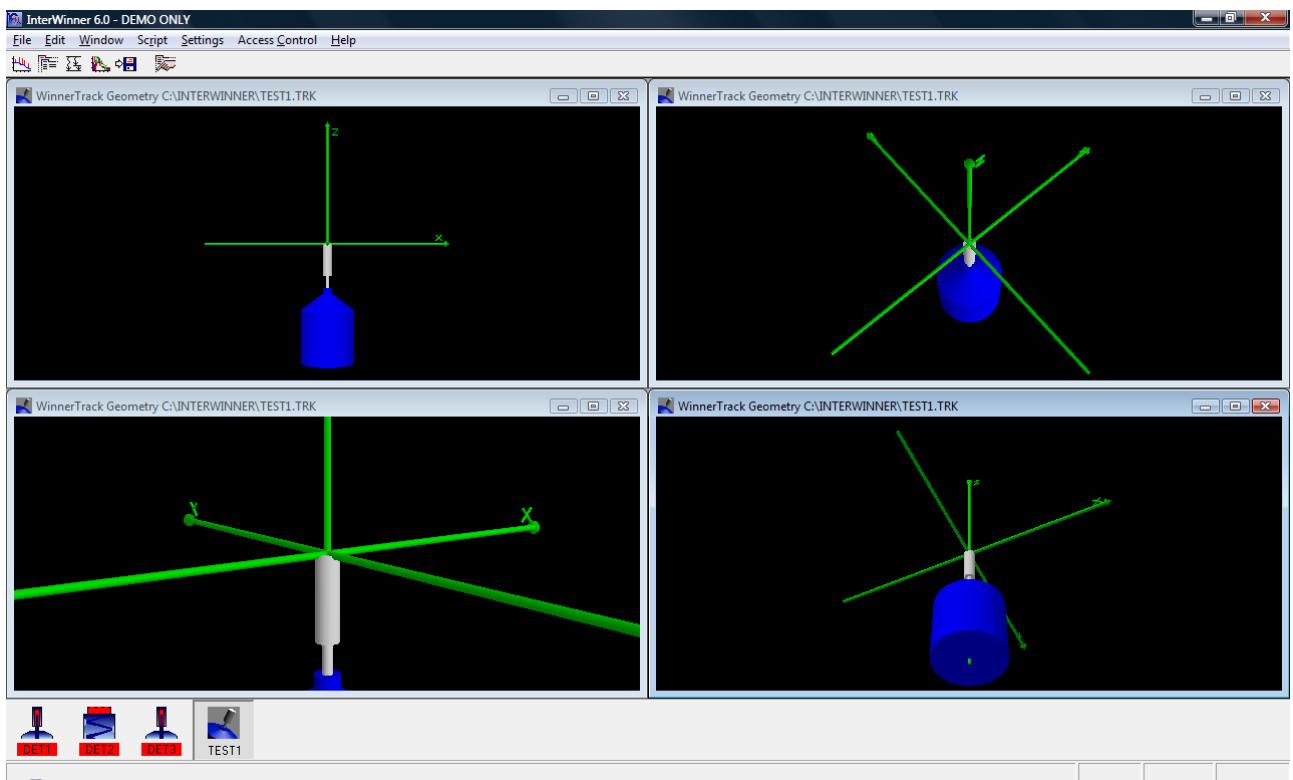




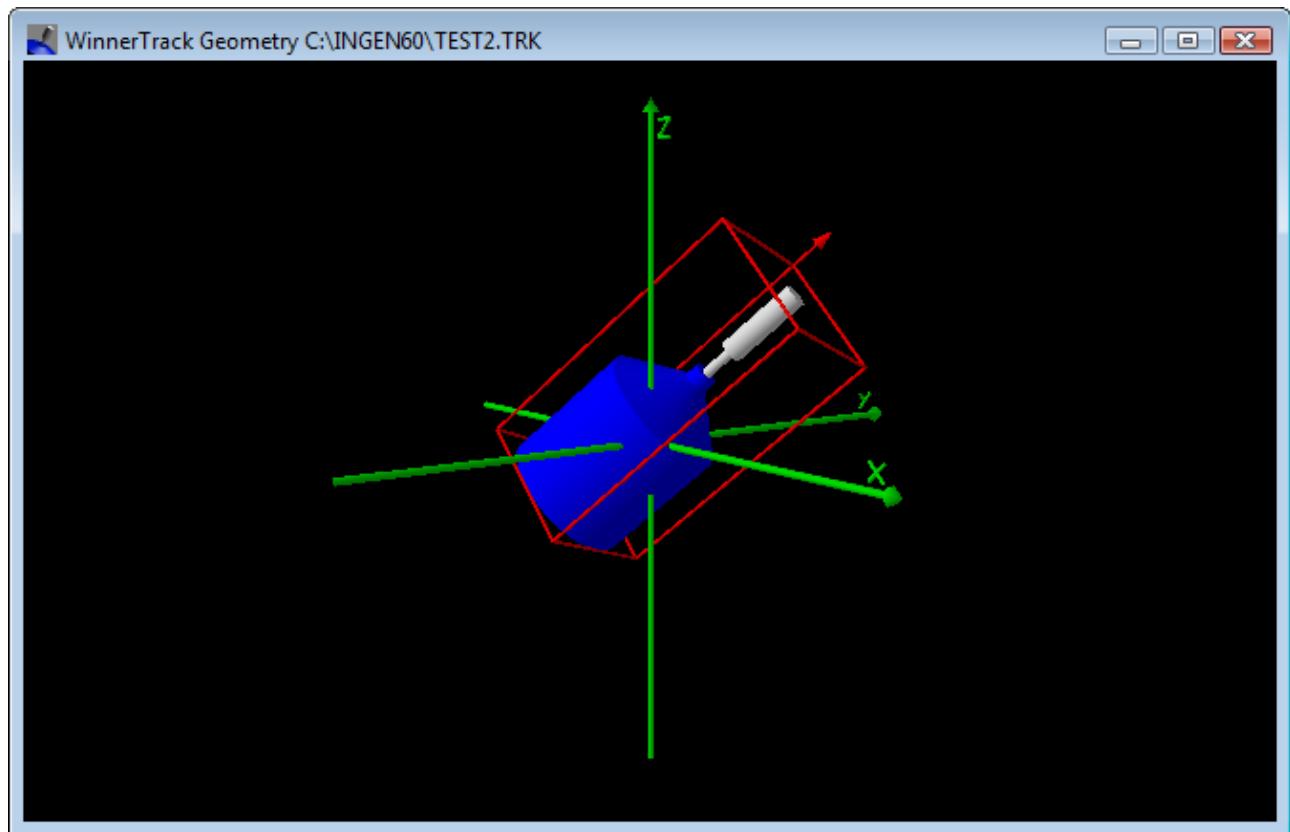
3.2 Graphical representation



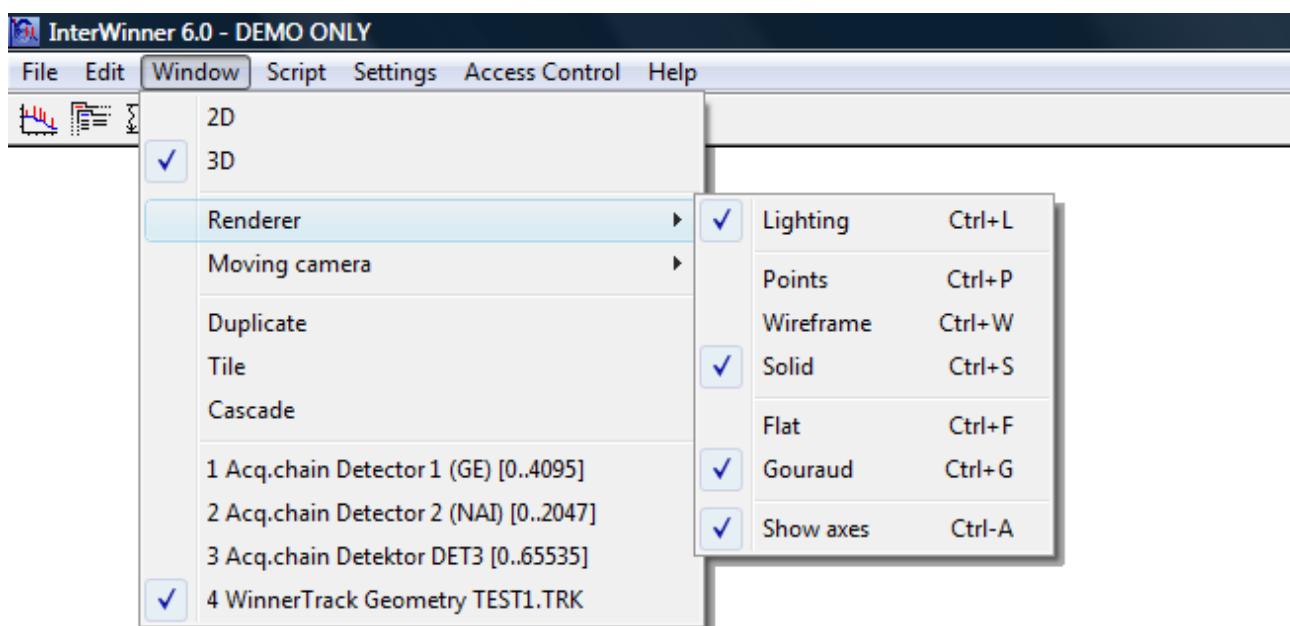
3.2.1 Changing the observer position



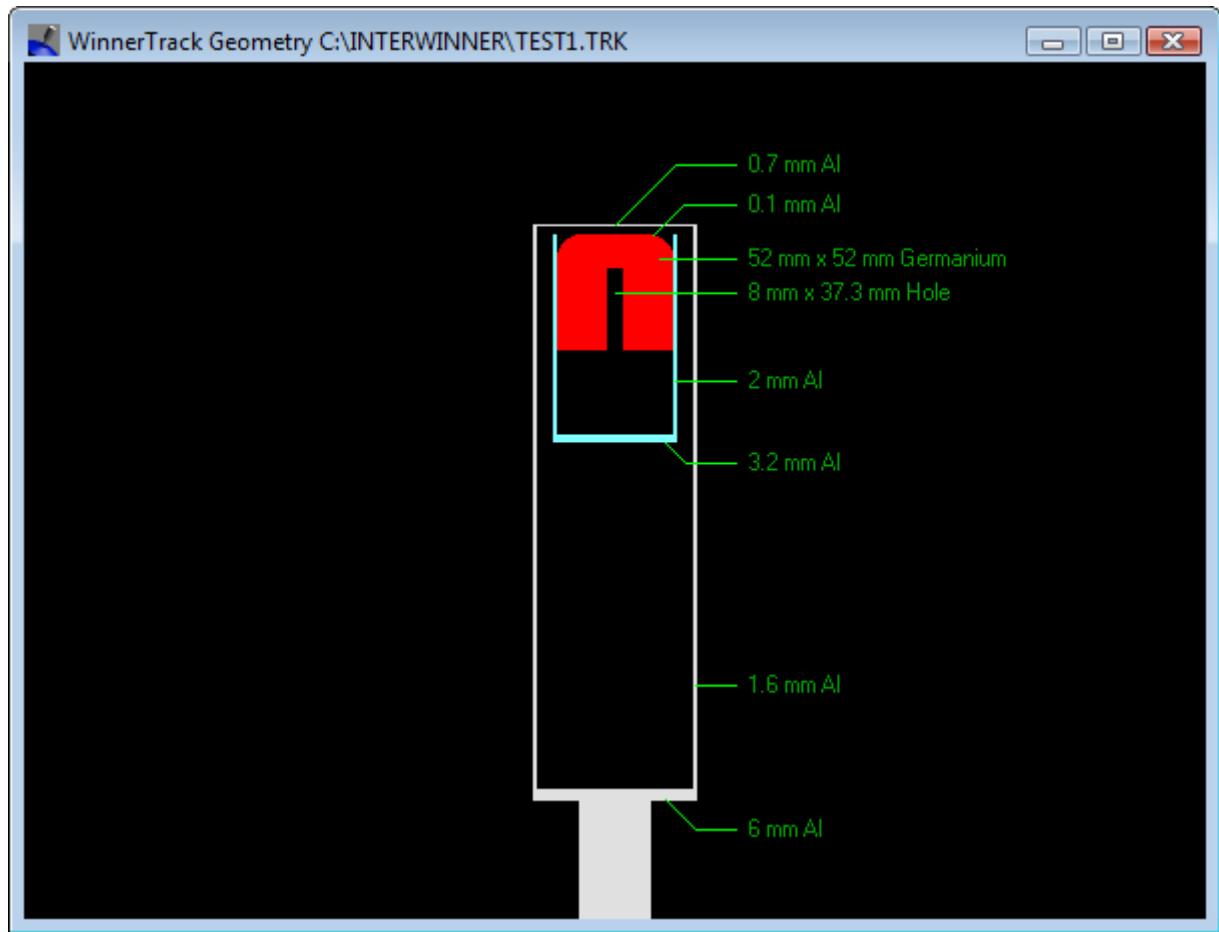
3.2.2 Moving and rotating objects



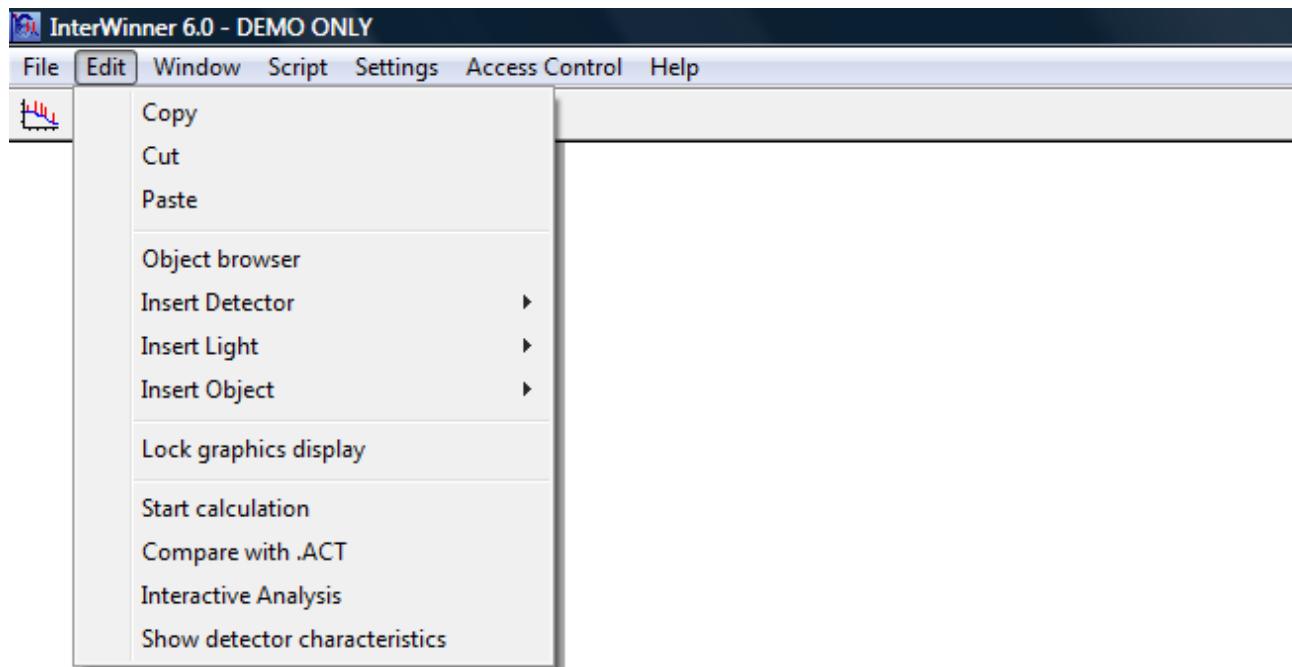
3.2.3 The window menu



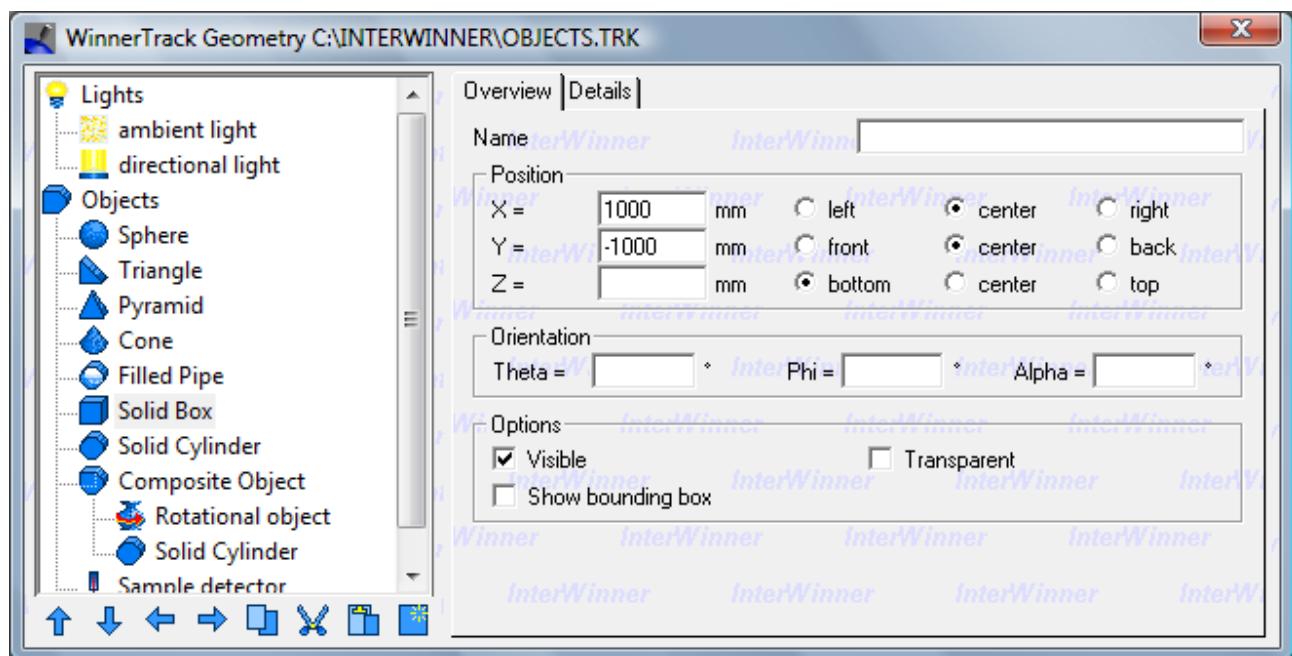
3.2.4 2-dimensional display



3.3 Editing the geometry



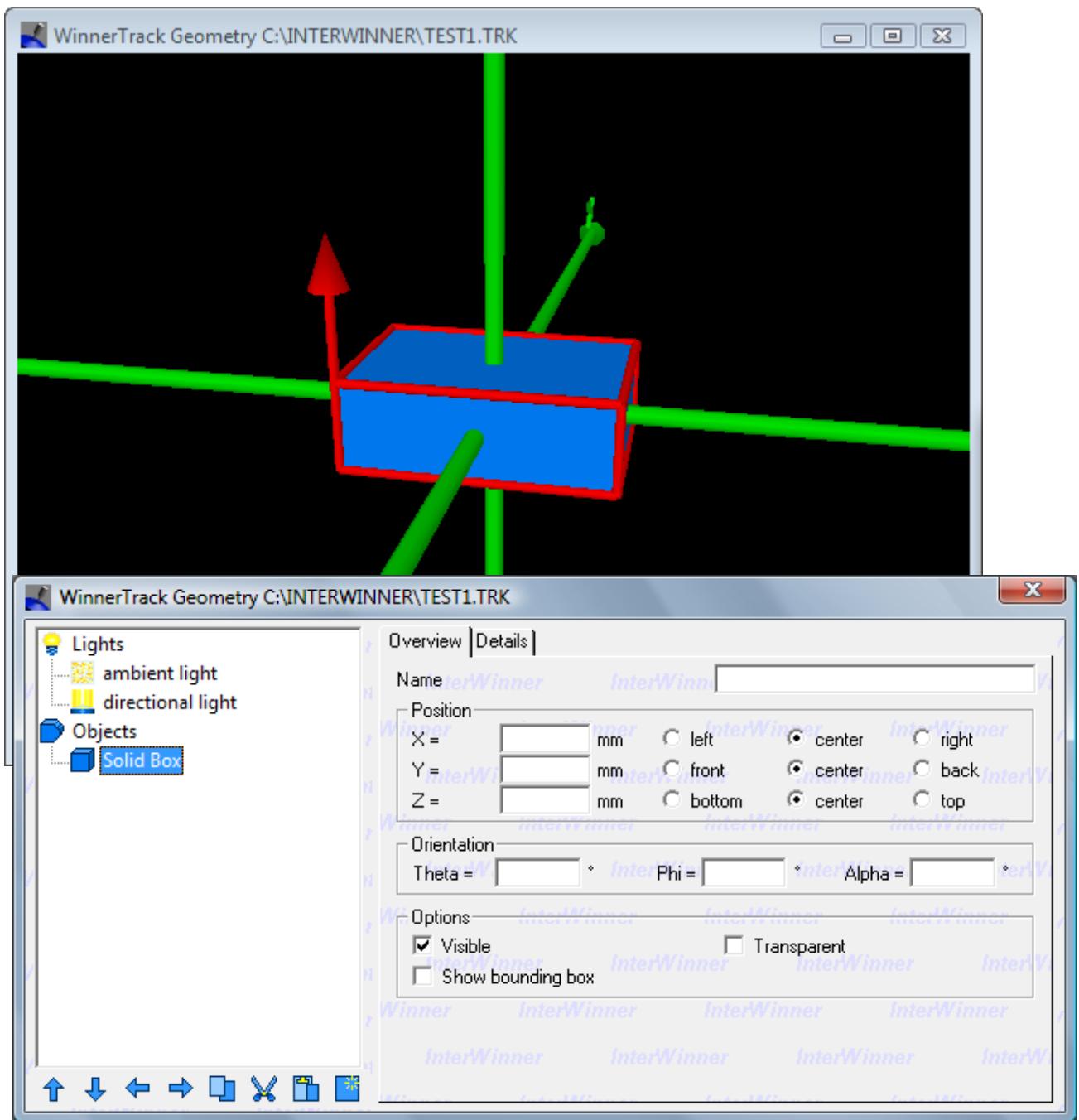
3.4 The object editor

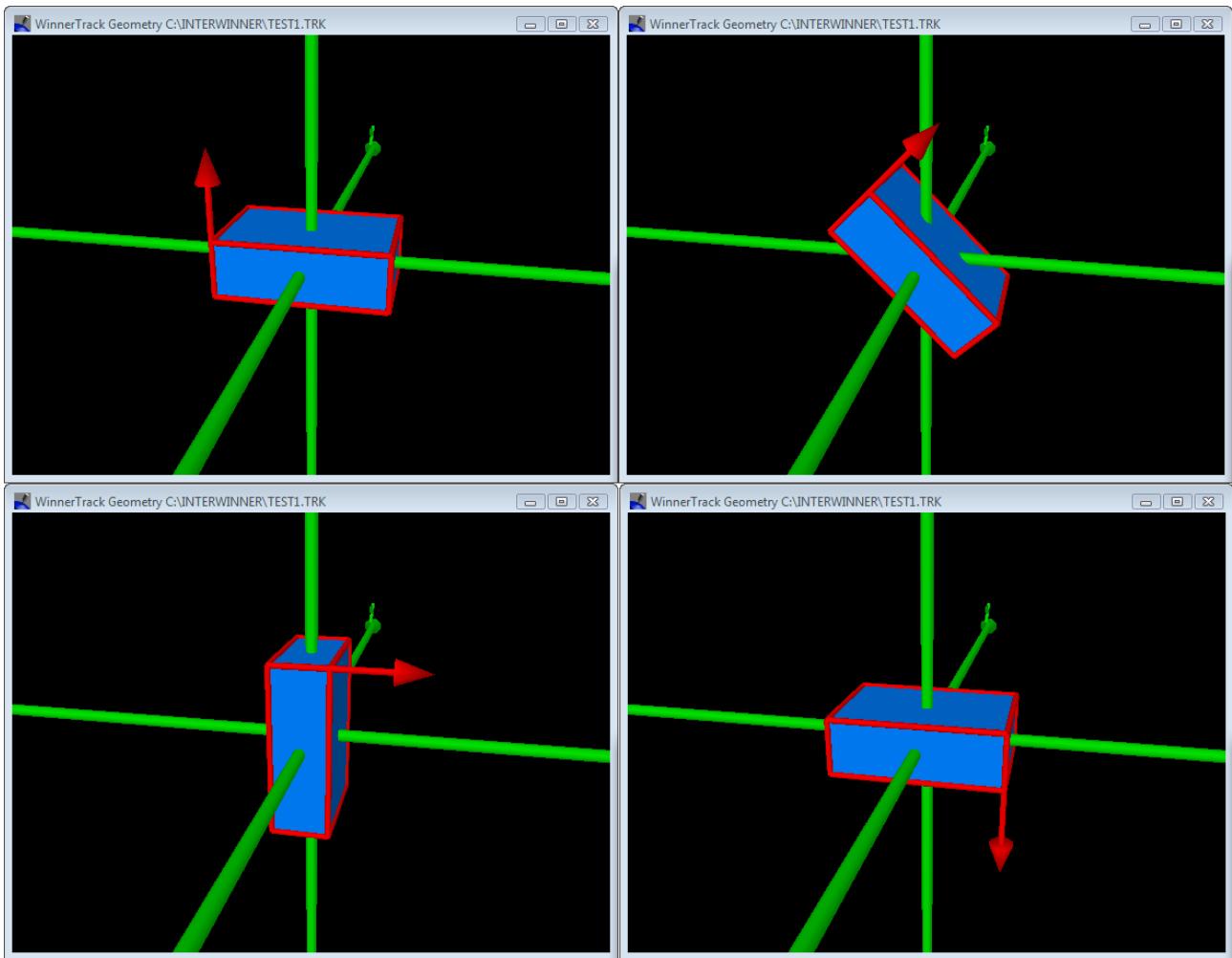


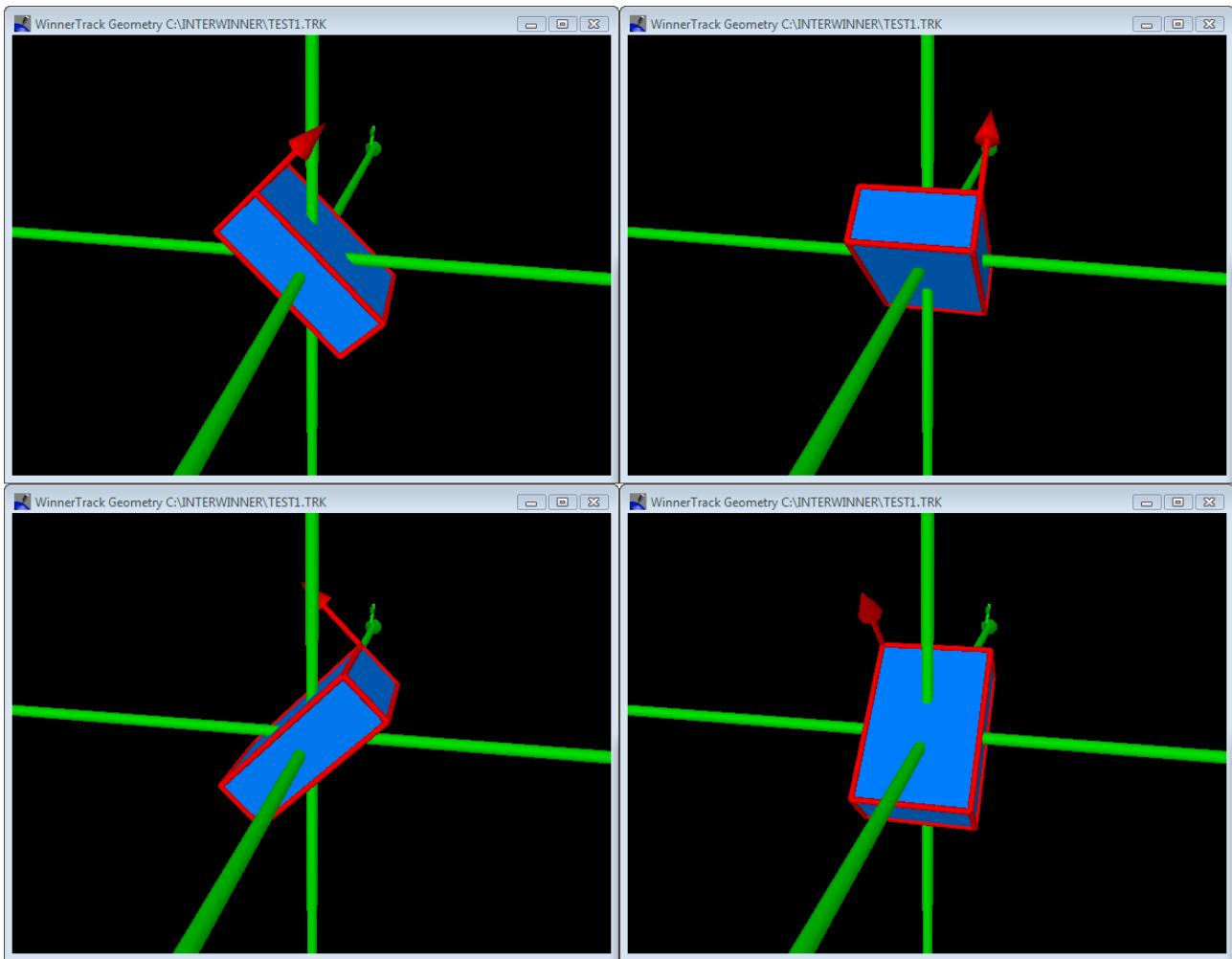
3.4.1 Tree view

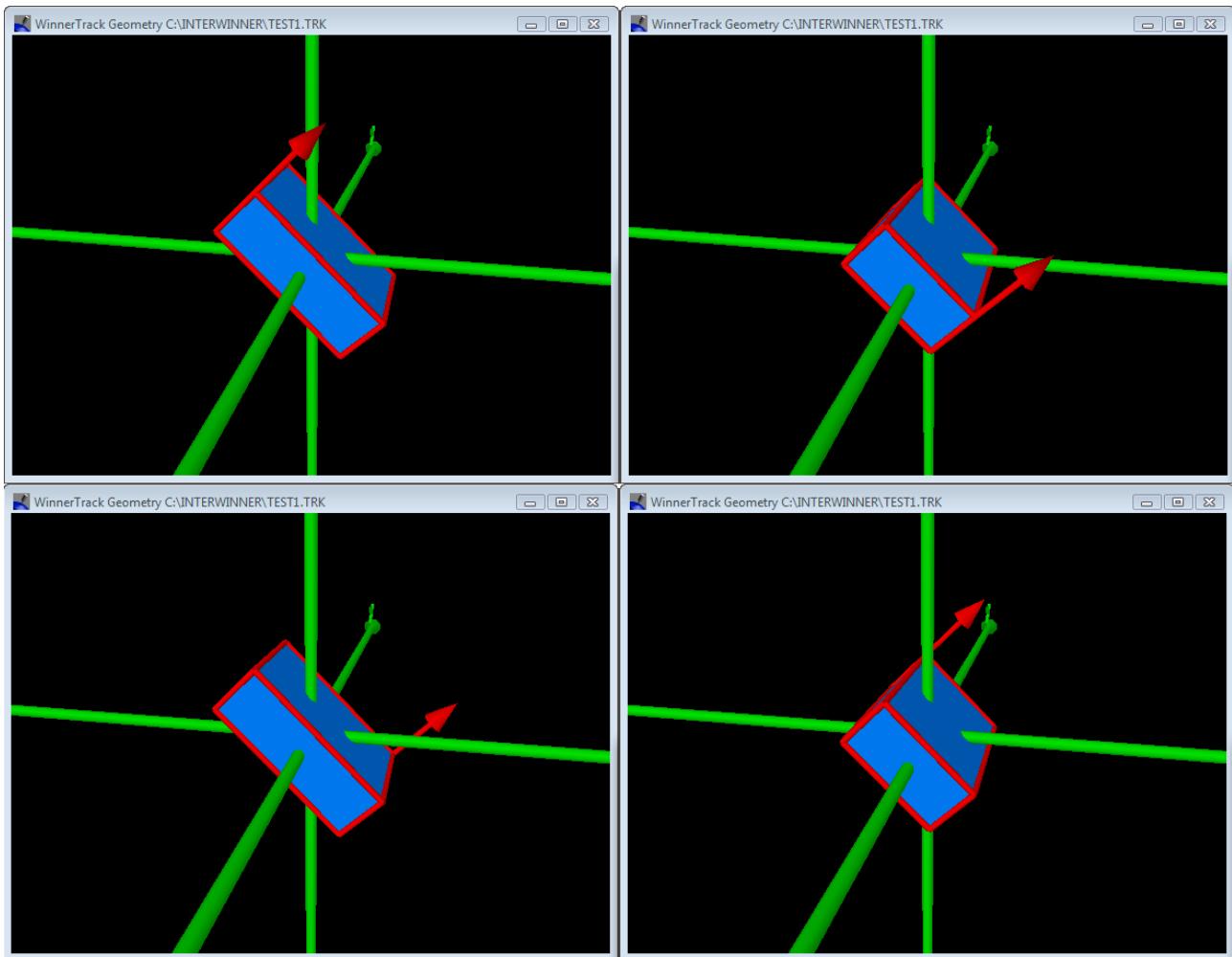
3.4.2 Command keys

3.4.3 The Overview dialog page

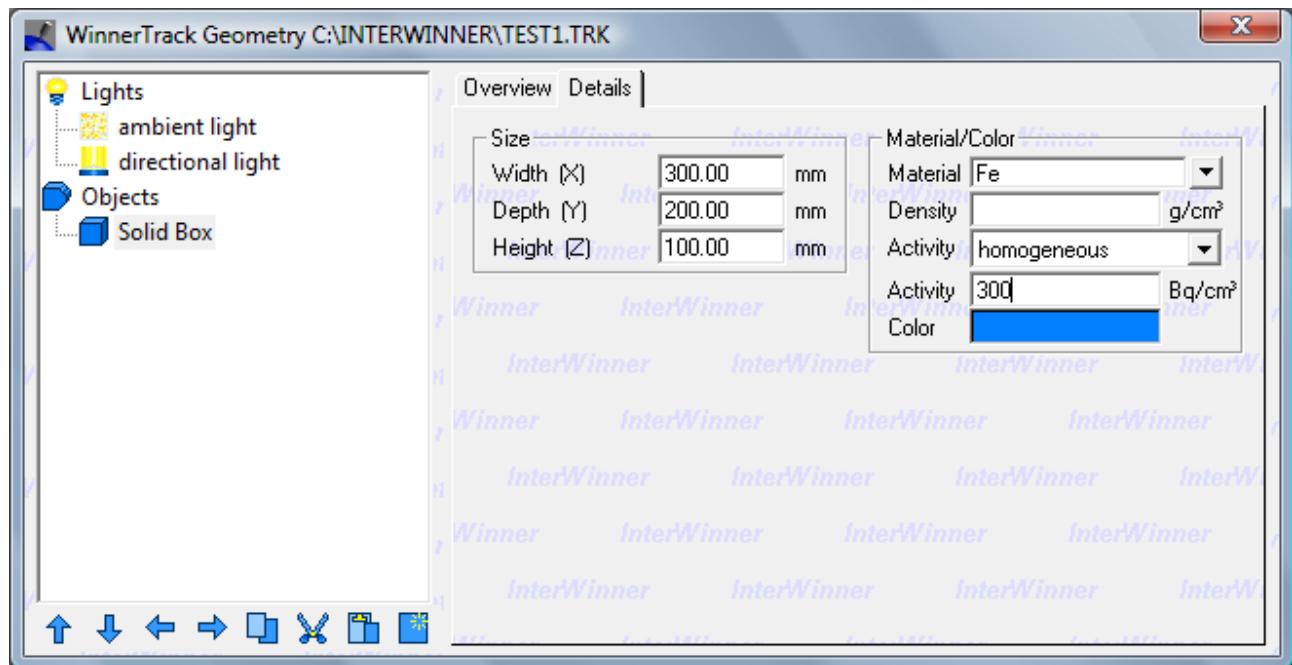








3.4.4 The details dialog page



4 Building a geometry

4.1 Introduction

WinnerTrack needs a precise description of the geometry of the setup in order to calculate the effective photon efficiency in the detector. The user must therefore model the geometry in the software. This is done using basic objects which are defined in WinnerTrack. The sizes, materials and positions of those objects can be selected by the user.

It is also possible to combine several of those objects to form a more complicated objects.

The available object types are described below.

4.2 Basic objects

Following basic objects are available in WinnerTrack:

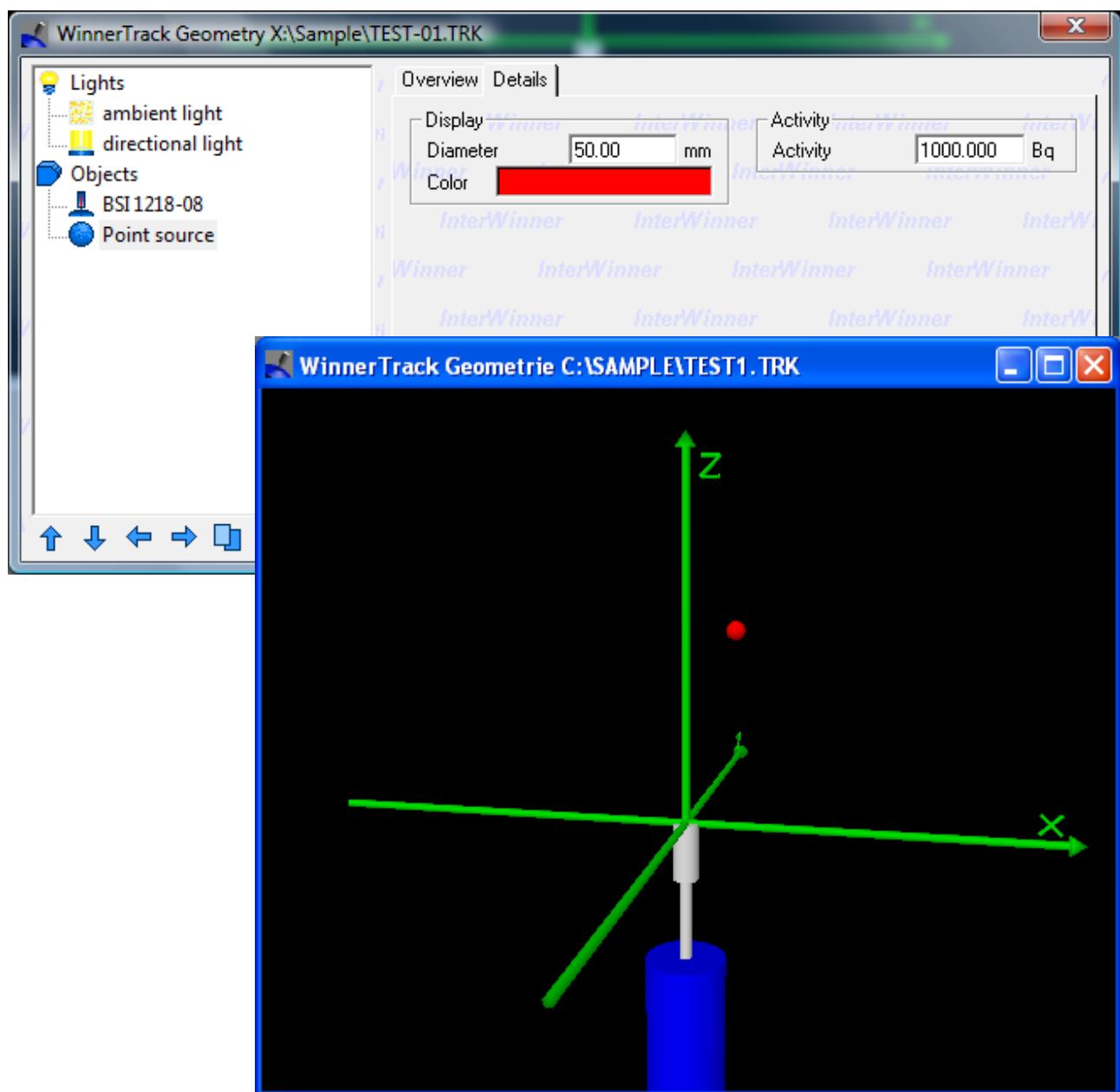
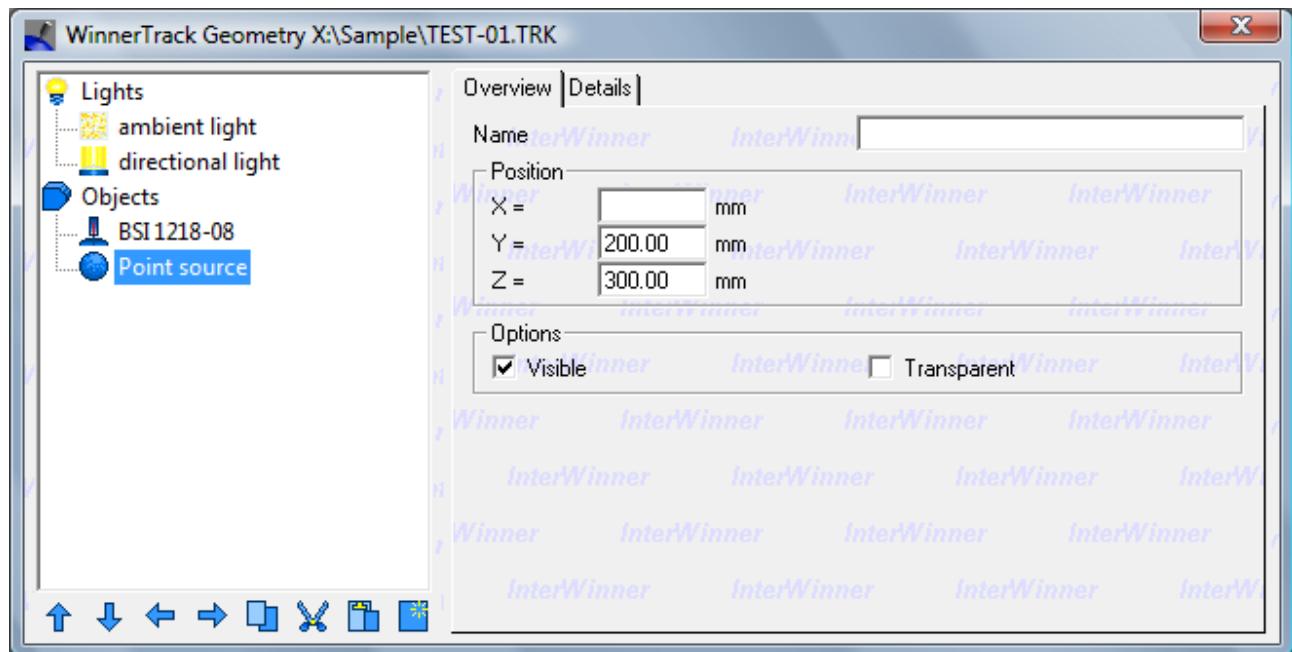
- Point source
- Box
- Triangle
- Pyramid
- Cylinder
- Cut cylinder
- Pipe
- Filled pipe
- Filled cylinder (barrel)
- Cone
- Rotationally symmetric object
- Marinelli-Beaker
- Sphere

The use of most of those objects is explained below. The other objects are simple and behave identical to the box object.

4.2.1 Point source

The point source differs from all other objects as it has no volume. Therefore the activity is given here not as volume activity but as integral activity. No volume means of course no absorption, therefore no material needs to be selected.

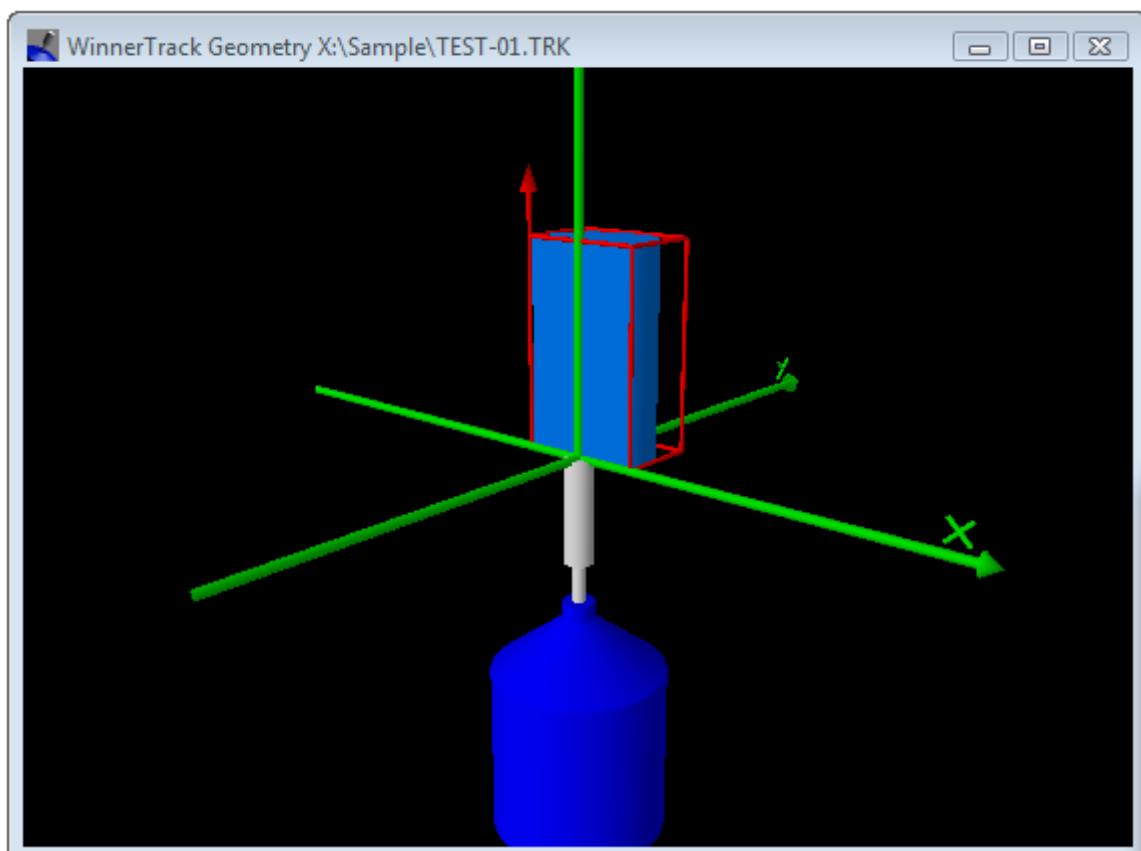
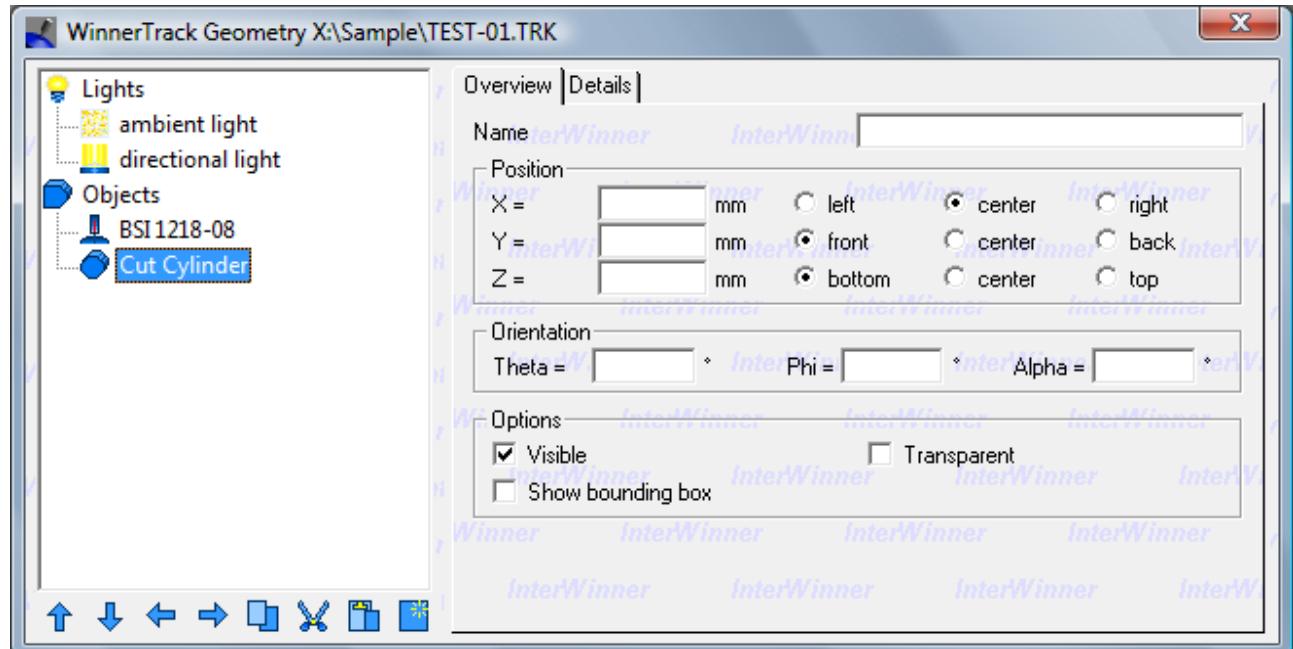
The diameter entered is only used for the graphical display as an infinitesimal point wouldn't be visible.



4.2.2 Cut cylinder

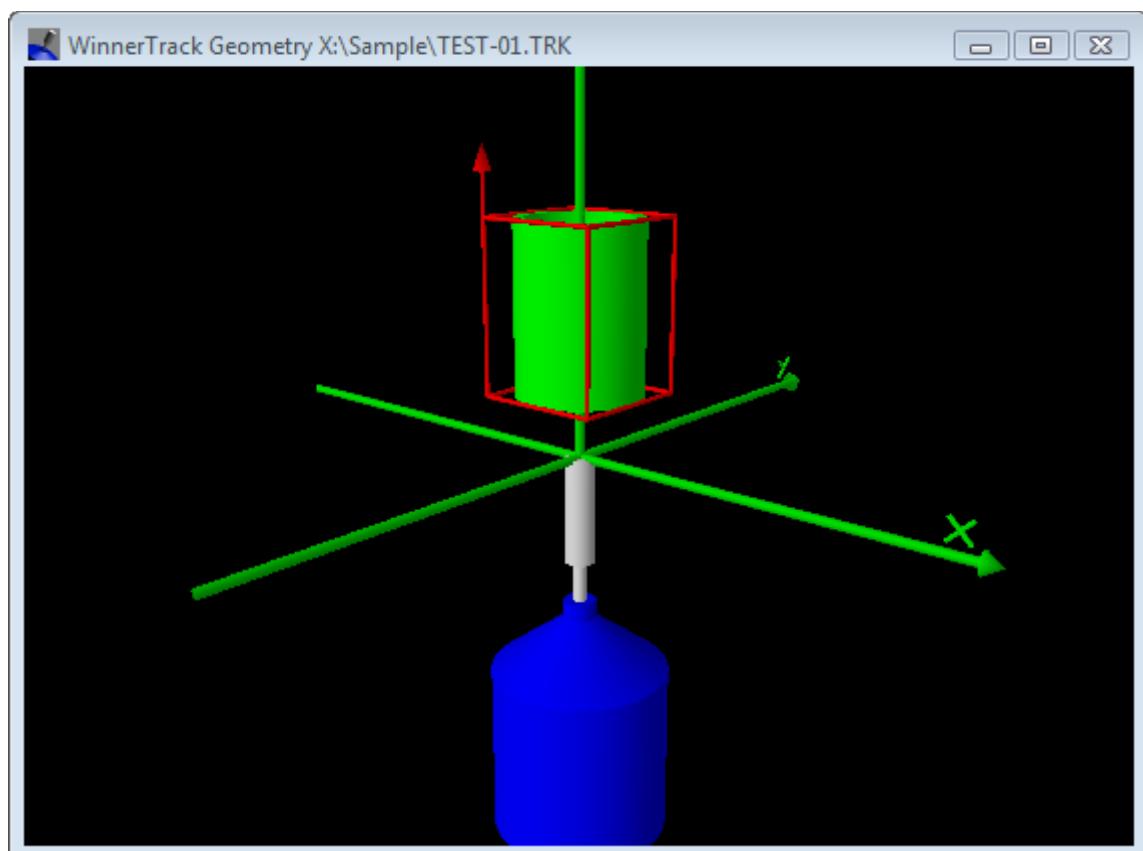
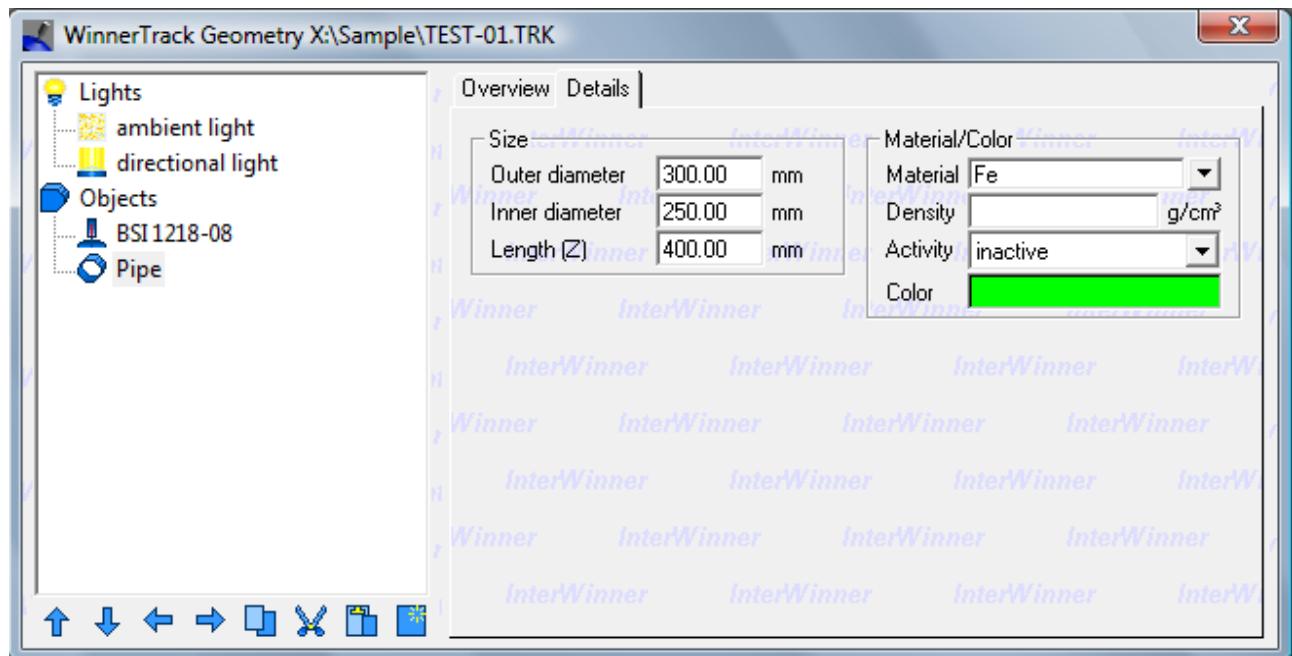
The cut cylinder is an object which uses instead of a circle a cut circle as base. This object is for example useful to create partly filled pipes. This is show in section 4.8.

The diameter in X direction is always the full diameter. The diameter in Y direction is the reduced/cut diameter and therefore must always be smaller than the diameter in X direction.



4.2.3 Pipe

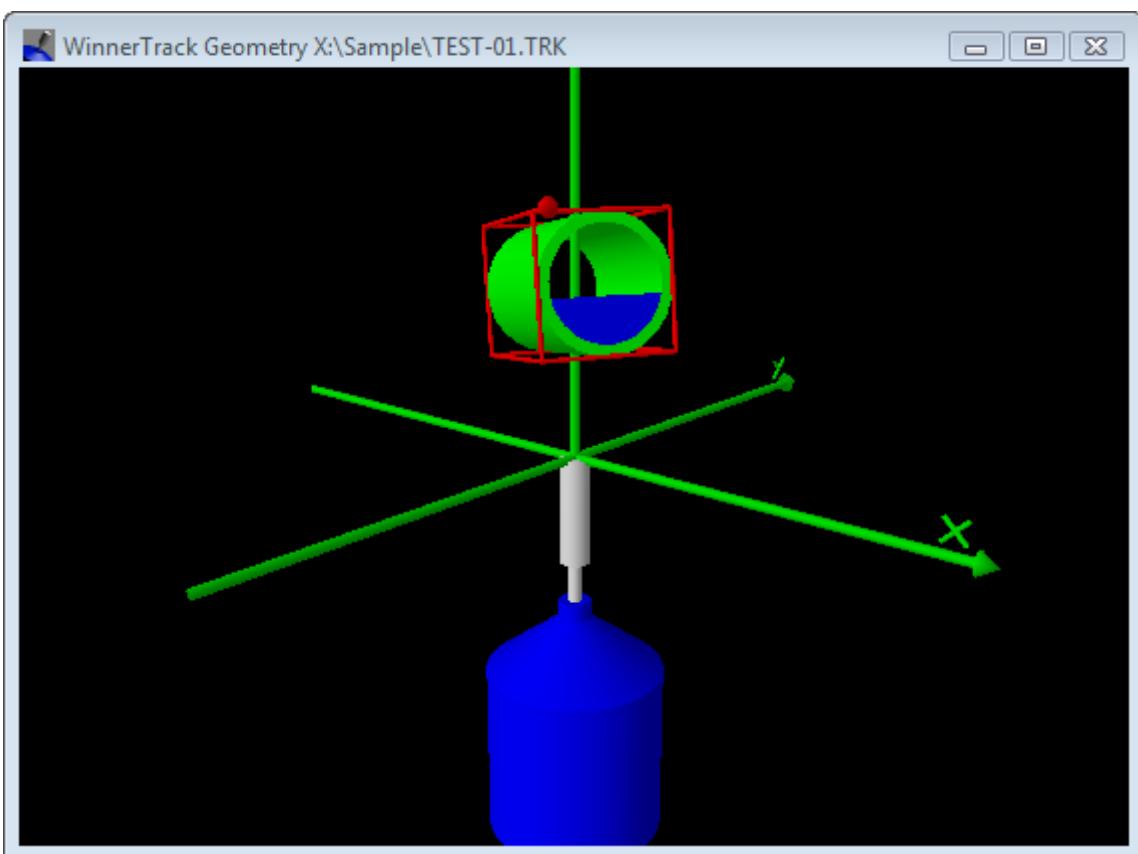
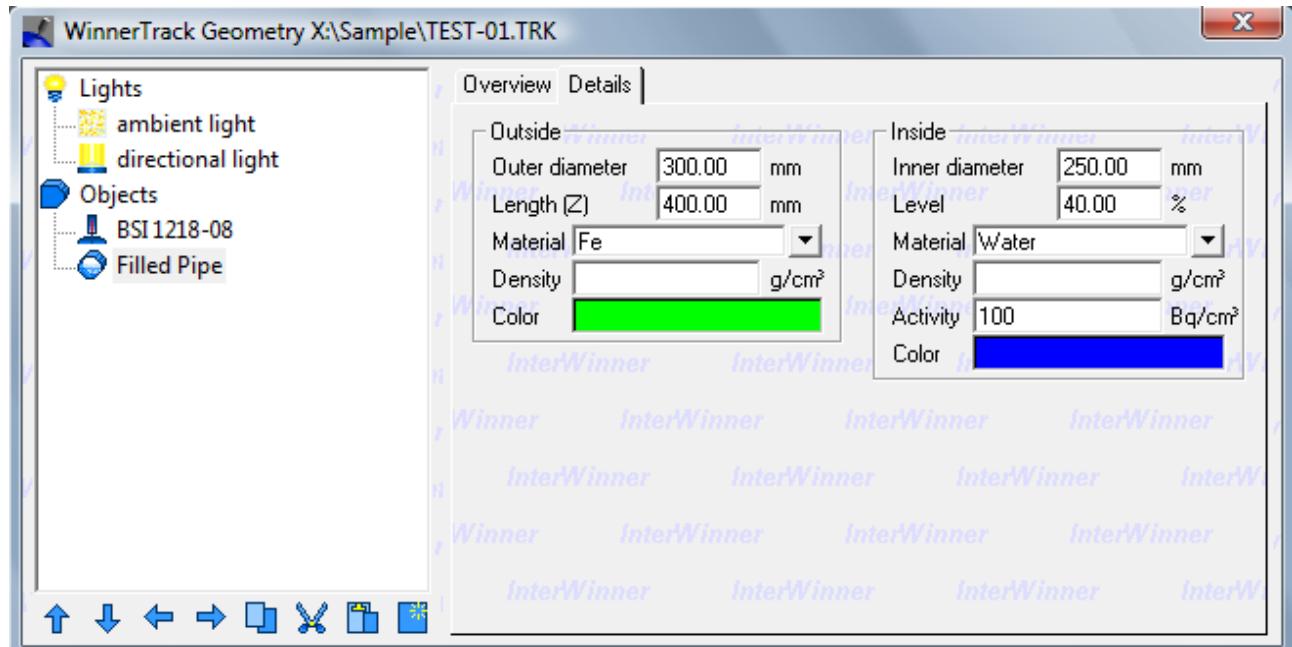
A pipe is a above and below open, hollow cylinder. The user has therefore to specify an inner and an outer diameter. The wall thickness is then half of the difference of the two diameters.



4.2.4 Filled pipe

Another basic object is the filled pipe. This is a pipe which contains additionally an internal material and a fill level. The internal material is positioned automatically according to the global Z axis. This simulates a liquid which always flows to the downward side of the pipe.

Only the the filling material, not the pipe itself, can be radioactive in the filled pipe object.¹

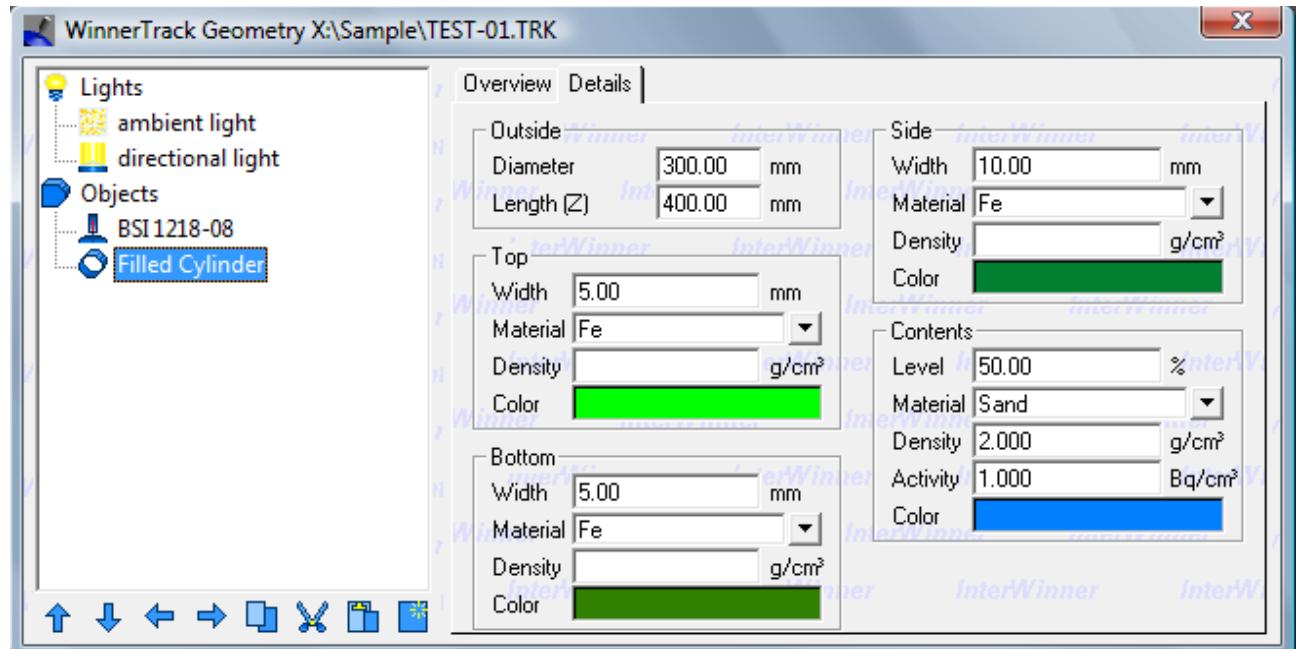


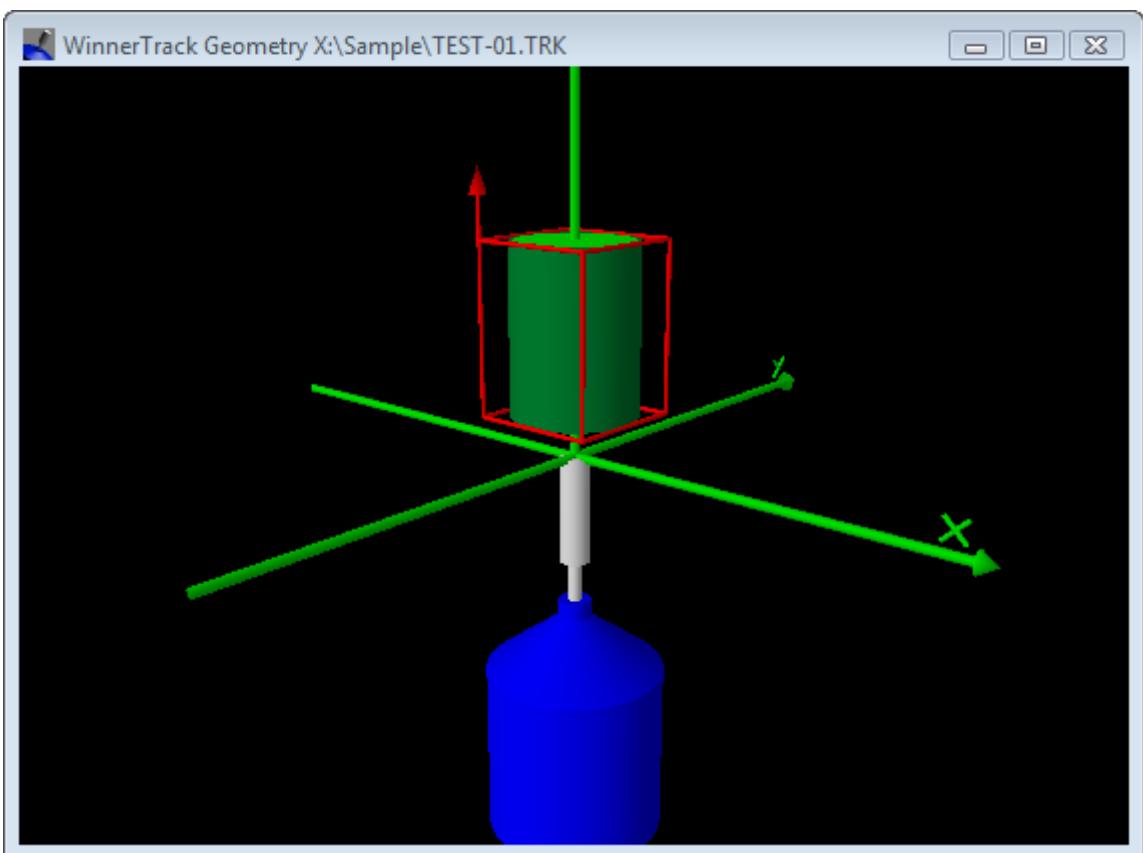
¹ Combine several objects to create a radioactive pipe if necessary.

4.2.5 Filled cylinder

This object can be used to simulate barrels or similar. The materials and thicknesses for the cover, the bottom and the jacket can be selected separately. A wall thickness of 0 is possible. The corresponding wall will then be removed and won't appear in the graphics display (e.g. Barrel without a cover).

The fill level of the content will be given in percent. The filling material will always be on the bottom of the cylinder; the external Z axis won't be taken into account.



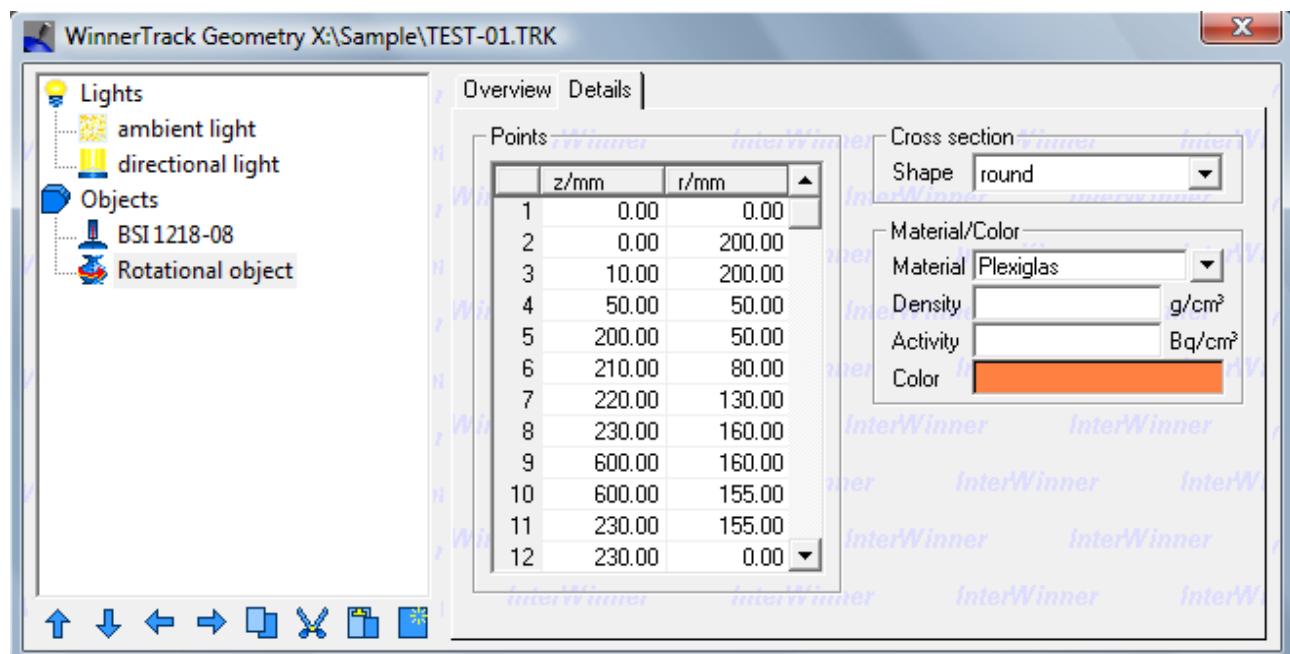


4.2.6 Rotational object

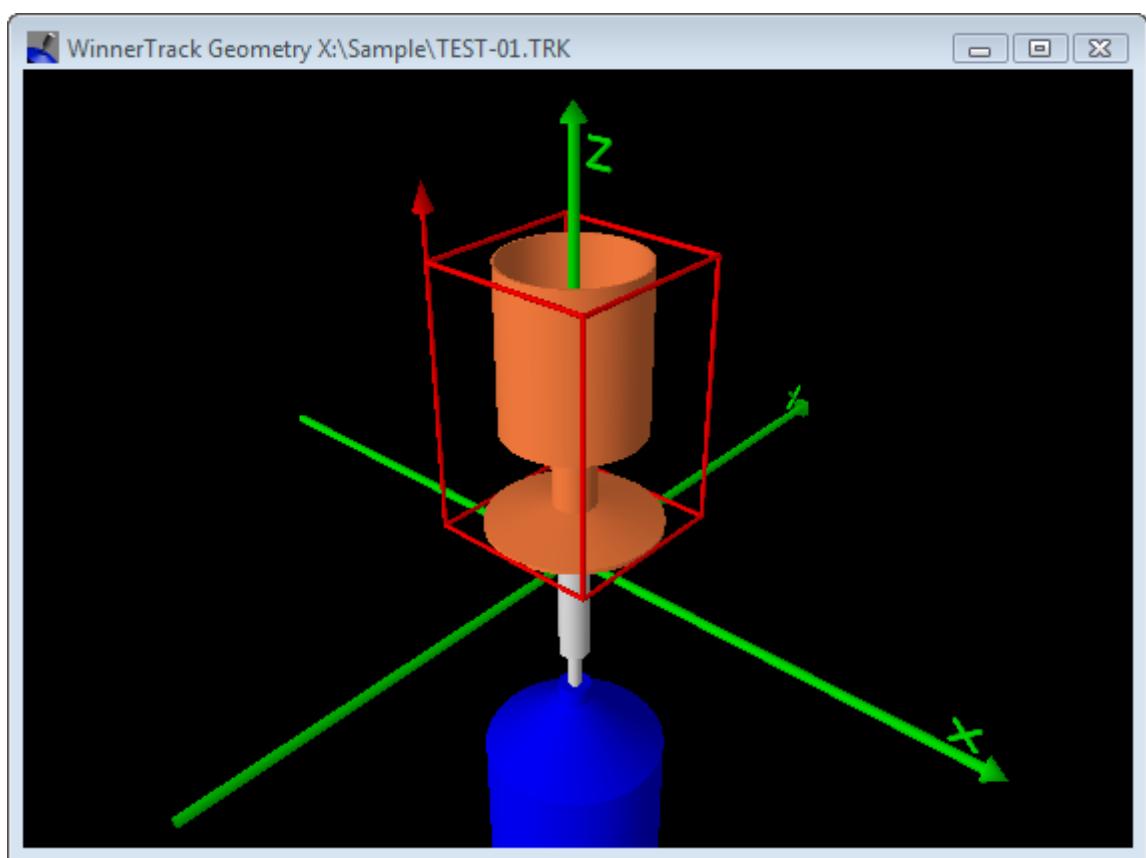
This object type is used to create arbitrary objects with cylindrical symmetry. The user has to enter the edge coordinates in the (r,z) plane. The points at the outside have to be given ordered from the bottom (lower z) to the top (higher z). The points on the inner side are given the other way round. This is necessary because the point order defines the orientation of the surfaces and this defines which points are inside and which are outside of the object.

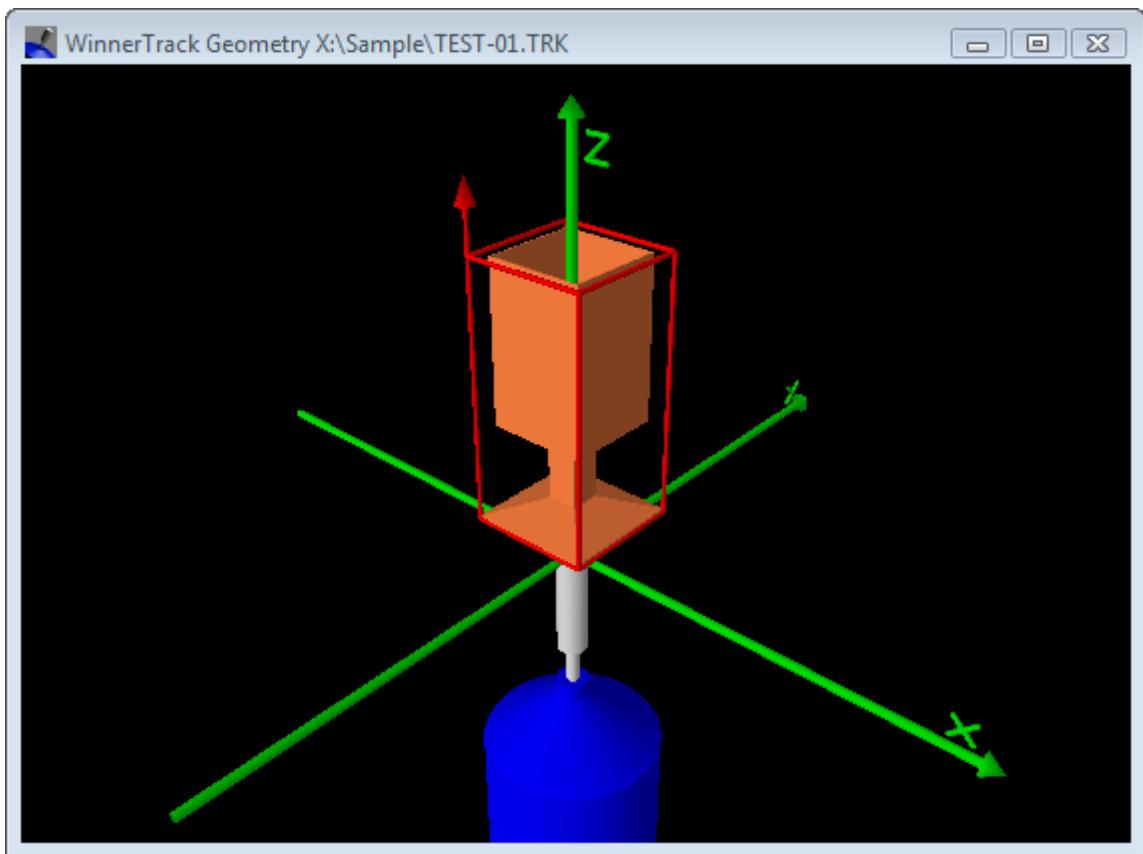
Errors in the orientation can be seen directly in the graphical display. The easiest way to correct the ordering is to replace all z values by their negative.

The absolute z coordinates are irrelevant. Only the differences of the different coordinates are relevant. This means that an object remains unchanged if one adds a constant (e.g. 1000 mm) to all coordinates. The reason is that the program calculates itself the center and the bounding box of the object and uses these for the subsequent calculations.



In addition to the cylindrical symmetry, this object type can also be used to create objects with 3 to 8-fold symmetry. An example is shown in the figure below.

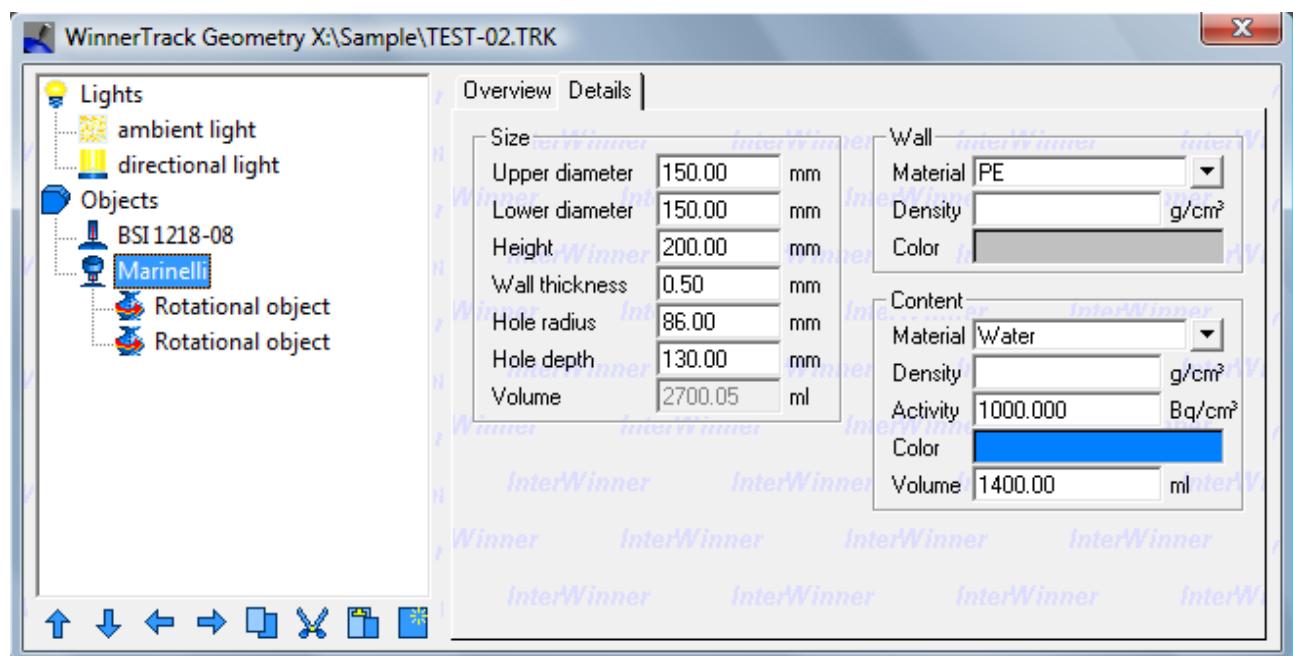




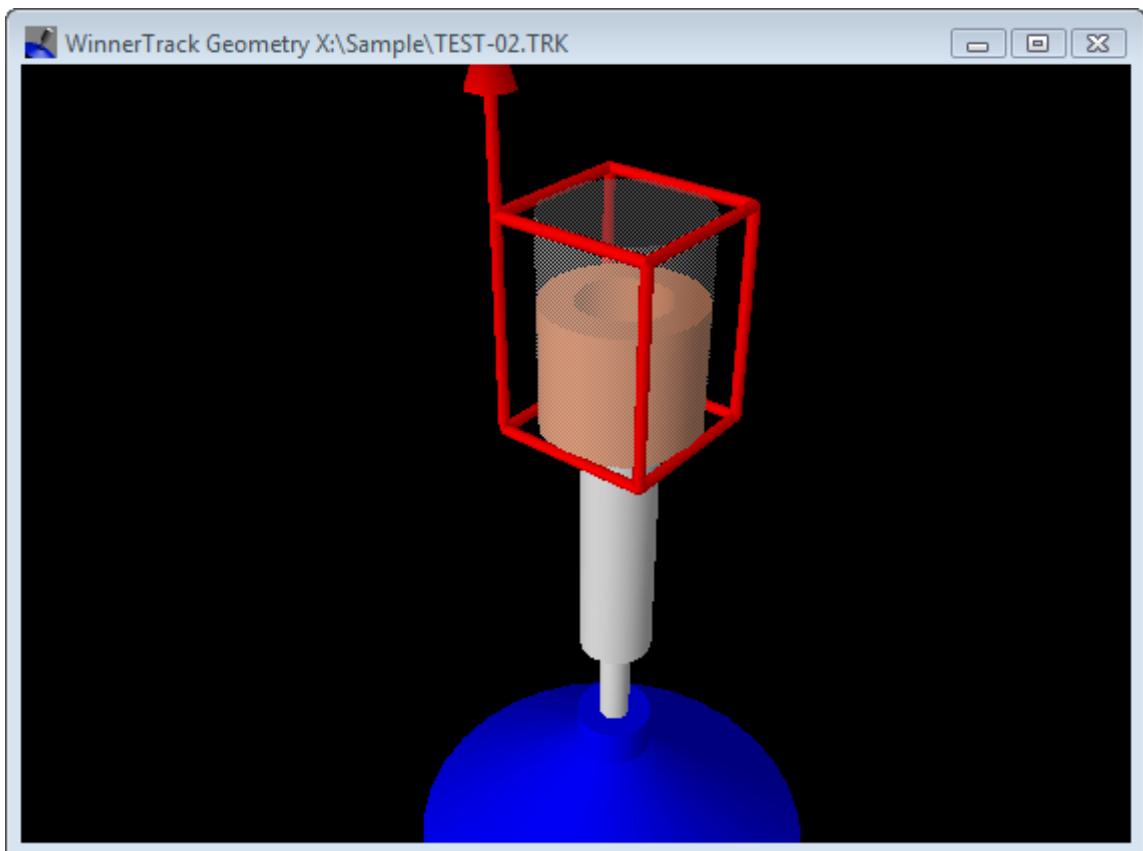
4.2.7 Marinelli

Another object type is used for the simulation of marinelli beakers. A specific marinelli beaker will be defined by upper and lower diameter², height, material and material thickness and the hole dimensions.

Internally, the marinelli will be handled as a composition of two rotational objects, one for the beaker and one for the content.



2 for conical beakers



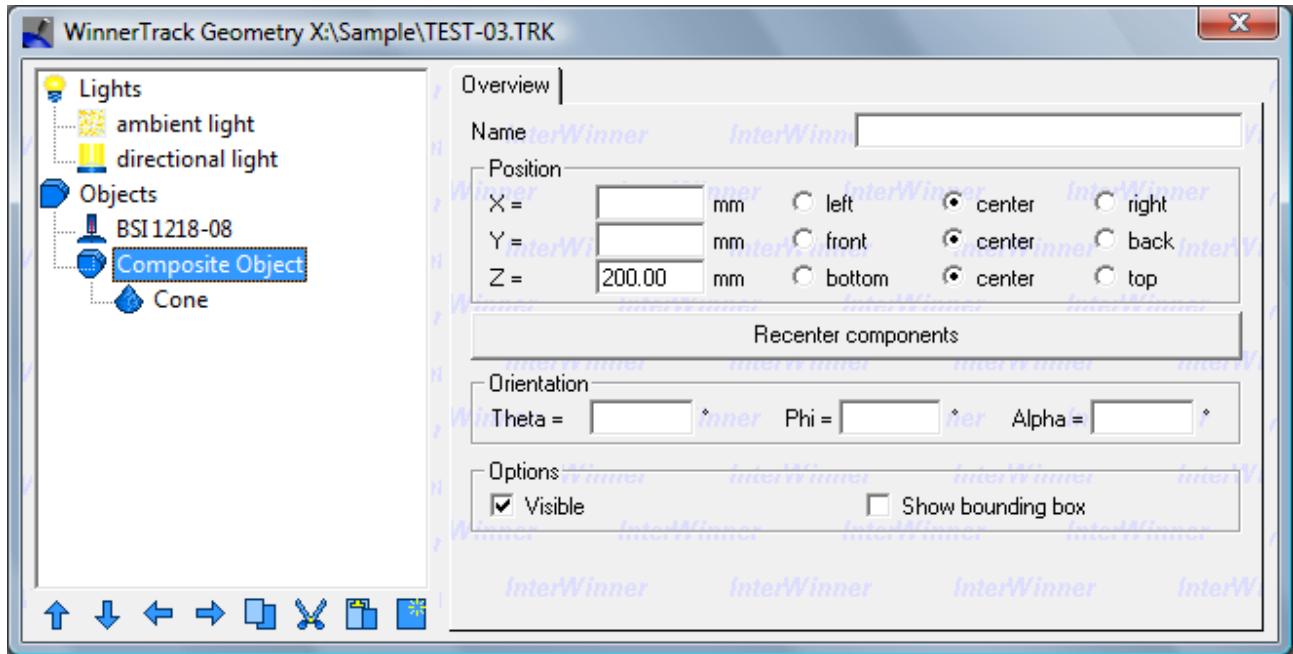
4.3 Composition of objects

The basic objects can be assembled to bigger objects. There are three different operations possible. Those operations correspond to the the possible operations in set theory. This can be expected as an object can also seen as set of all points which lie inside the object.

A composed object has its own coordinate system. The positions and orientations of the constituting objects are always relative to this coordinate system. It is possible to compose an object not only of basic objects but also of composite objects. This means that one has a hierarchy of coordinate systems. This can make the handling difficult, especially if to coordinate systems are rotated against one another. It is therefore recommended to position the partial objects first correctly and then start moving the composite object from the initial position.

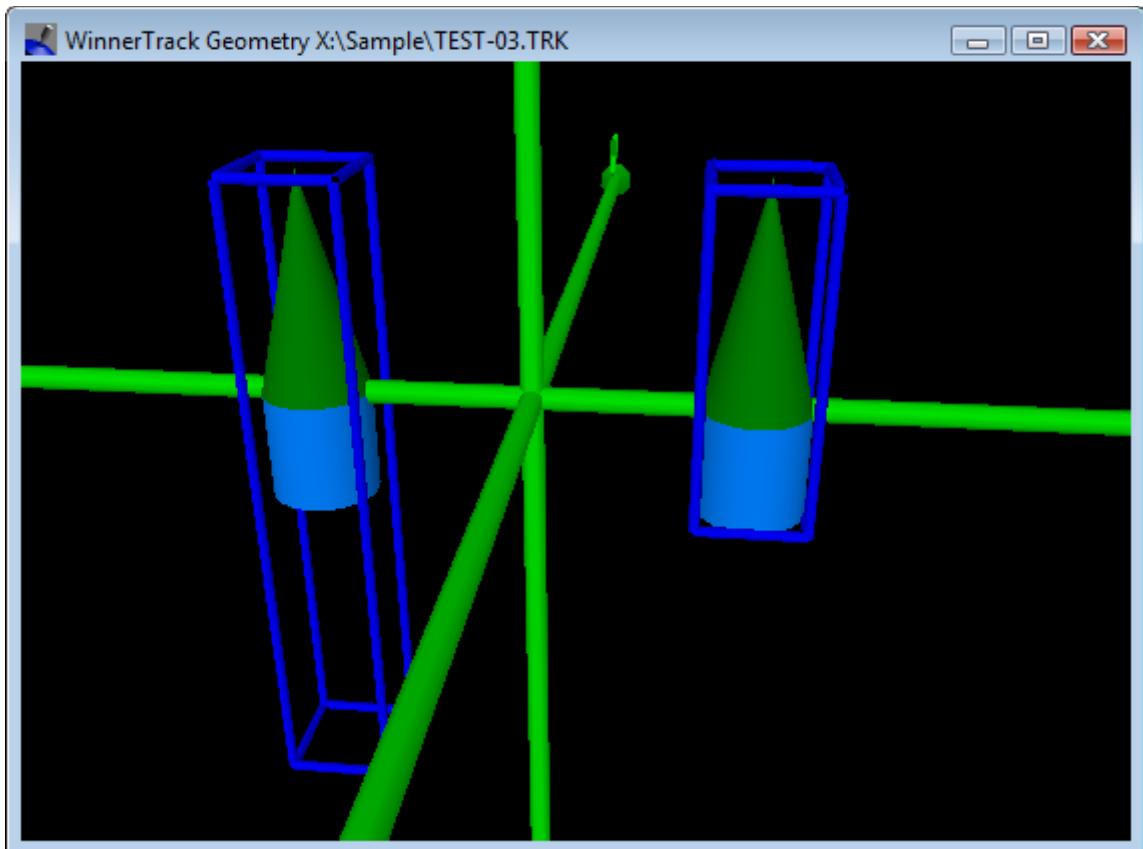
The object editor is used in order to move objects in and out of an composed object. One may mark the object, cut it out, select the composite object and then paste the object in. The other possibility is to move the object with the arrow keys (up and down) below the composed object and then use the right arrow to move the object into the composed object. The left arrow can be used in the same way in order to take out an object of the composed object.

The next picture shows the parameter dialog box for a composed object. There are the position coordinates and the orientation parameters as for normal objects. As the composing objects live in this coordinate system of the composition object moving or turning this object will affect all part objects.



A new button is the button [Recenter components]. The idea behind this button is that the partial objects are not necessarily created symmetrically around the reference point of the composite object. The result is that the bounding box is larger than necessarily and that rotating the composite object rotates it around the center of the bounding box – which isn't the center of the visible objects.

This button repositions all partial objects and the composed object in a way that all partial objects keep their position in the outer coordinate system but the bounding box becomes as small as possible. An example of a composed object before and after recentering is shown in the next figure.



The different possibilities for object compositions are explained in the next sections. Please note that the graphics makes no difference between combined, intersection or difference objects. It is recommended to use the test beams (section 4.5) for a better understanding.

Composed objects can be moved, rotated, erased and copied just like ordinary objects.

4.3.1 Composite object

This object is simply the set of all points which belong to one of the partial objects. If objects intersect then the properties (material, density, activity) of the object which appears last in the object editor are used.

This composite object is mainly for a better structuring of the geometry setup.

4.3.2 Difference of objects

This object is defined as the set of all points which belong to the first partial object but not to any of the other partial objects. Only the object properties of the first partial object are used – the other partial objects are only geometrical and have no physical properties.

An example for this object type may be a bowling ball. This is a sphere minus some cylindrical holes.

4.3.3 Intersection of objects

This composed object consists of all points which are inside of all of the partial objects. Only the object properties of the first object are used.

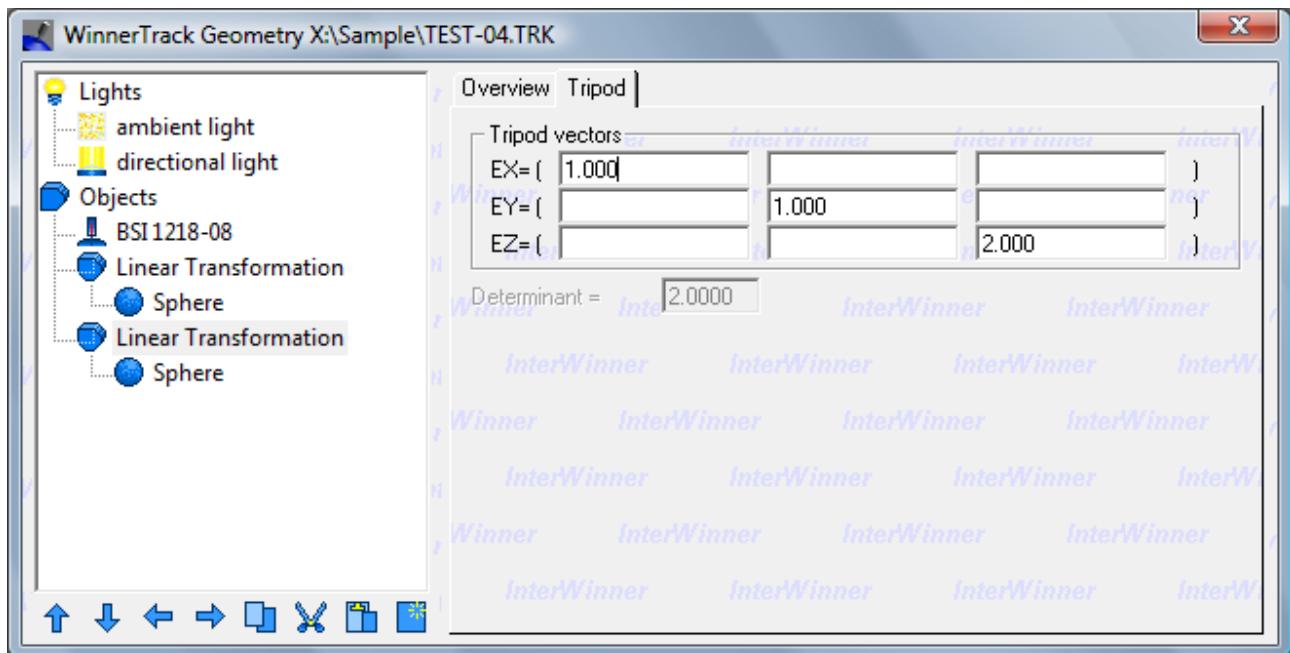
4.4 Linear transformation

The linear object is similar to the composite object. We have seen that the partial objects live in the coordinate system of the composite object. This local coordinate system could be rotated or shifted compared to the outer coordinate system. However it was always a Cartesian coordinate system: The generating vectors were always perpendicular and of length one.

The linear transformation object type doesn't have this restriction. The user can freely define the generating vectors of the local coordinate system. Those vectors need no longer to be perpendicular which creates a distorted coordinate system.

The vectors also need no longer to have equal length. This permits to prolongate or shorten one or more of the directions in the object. For instance, one can transform a sphere into a rotational ellipsoid by modifying the length of the z vector.

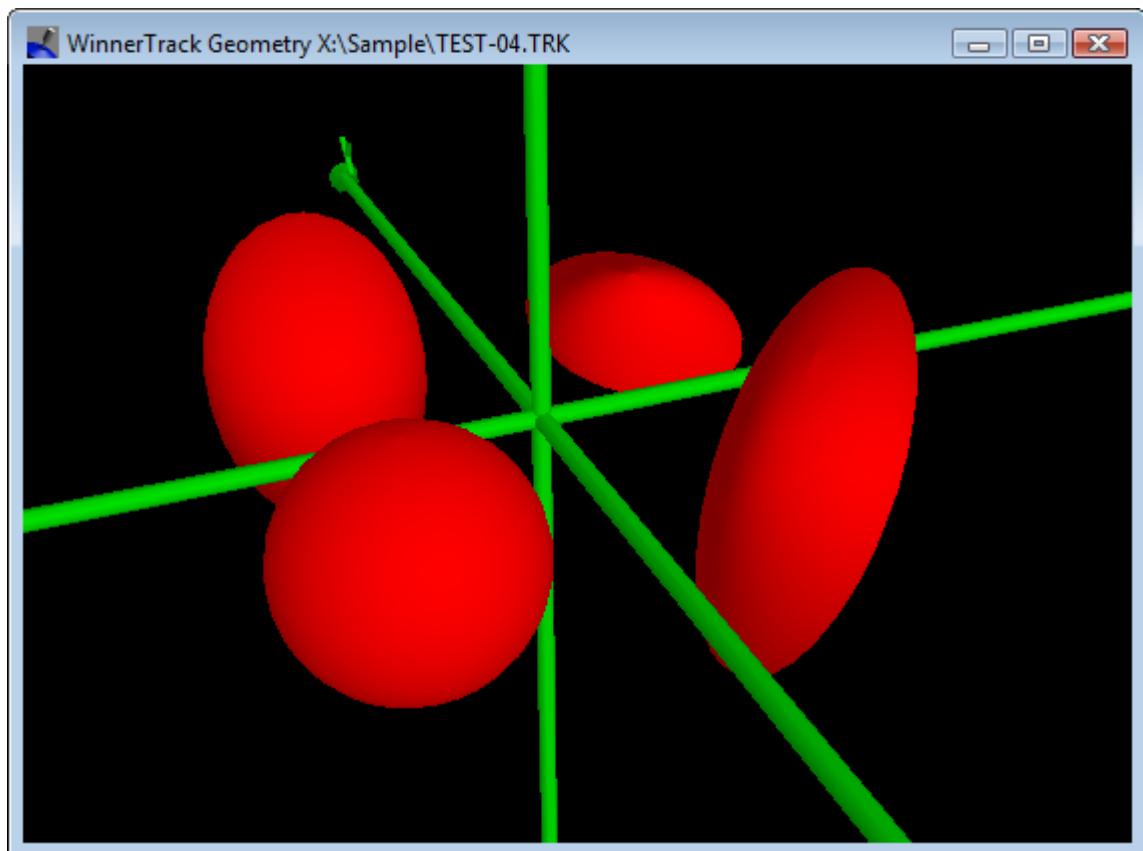
Of course these operations can be used for all types of composing objects.



The generating vectors have to be selected in the object editor. The classical Cartesian vectors are predefined. For these generating vectors the linear transformation object will behave identical to the composite object.

The program shows the determinant of the resulting transformation matrix. If this determinant is 1 then the transformation will not change the volume of the objects. Values greater than 1 correspond to an increase of the volume, values smaller than one correspond to a decrease of the object volume. The three generating vectors shouldn't be linearly dependent. Otherwise the determinant will be zero and the objects will be reduced to mere surfaces.

The next figure shows a sphere in four different transformations.

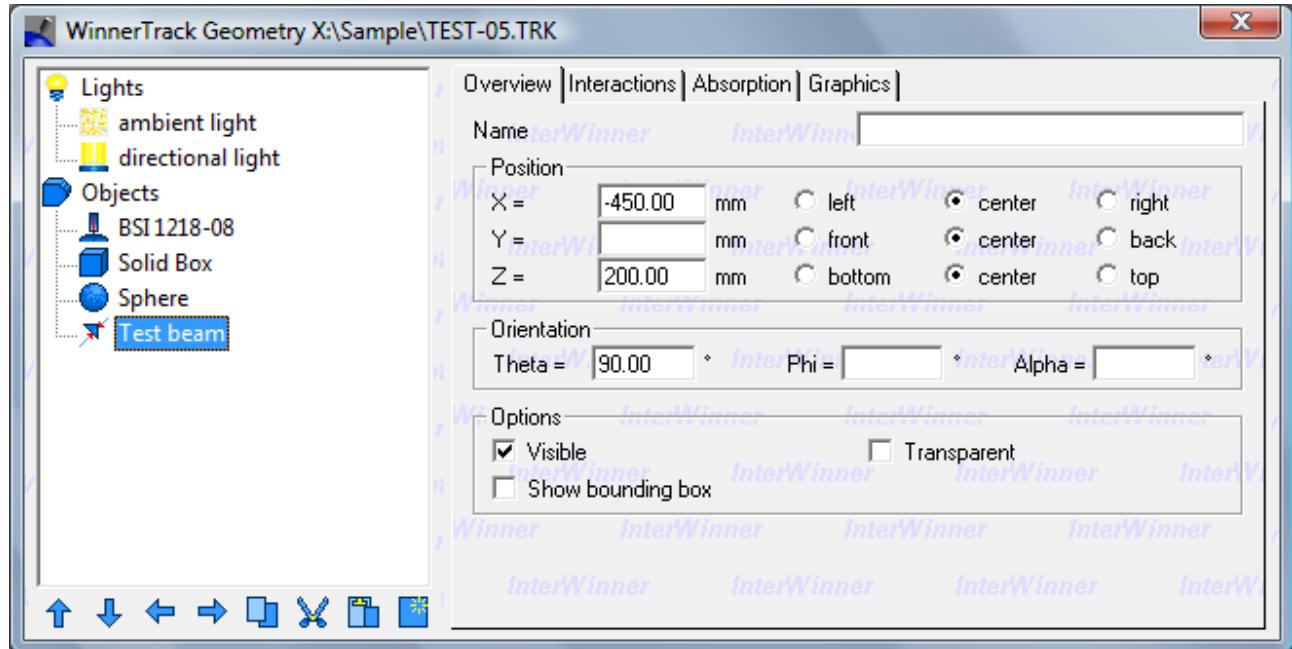


4.5 Test beams

Especially when working with complex geometries (e.g. overlapping objects) it may be difficult to see the correctness of the geometry only using the graphical display. A tool to check the geometry further are the test beams.

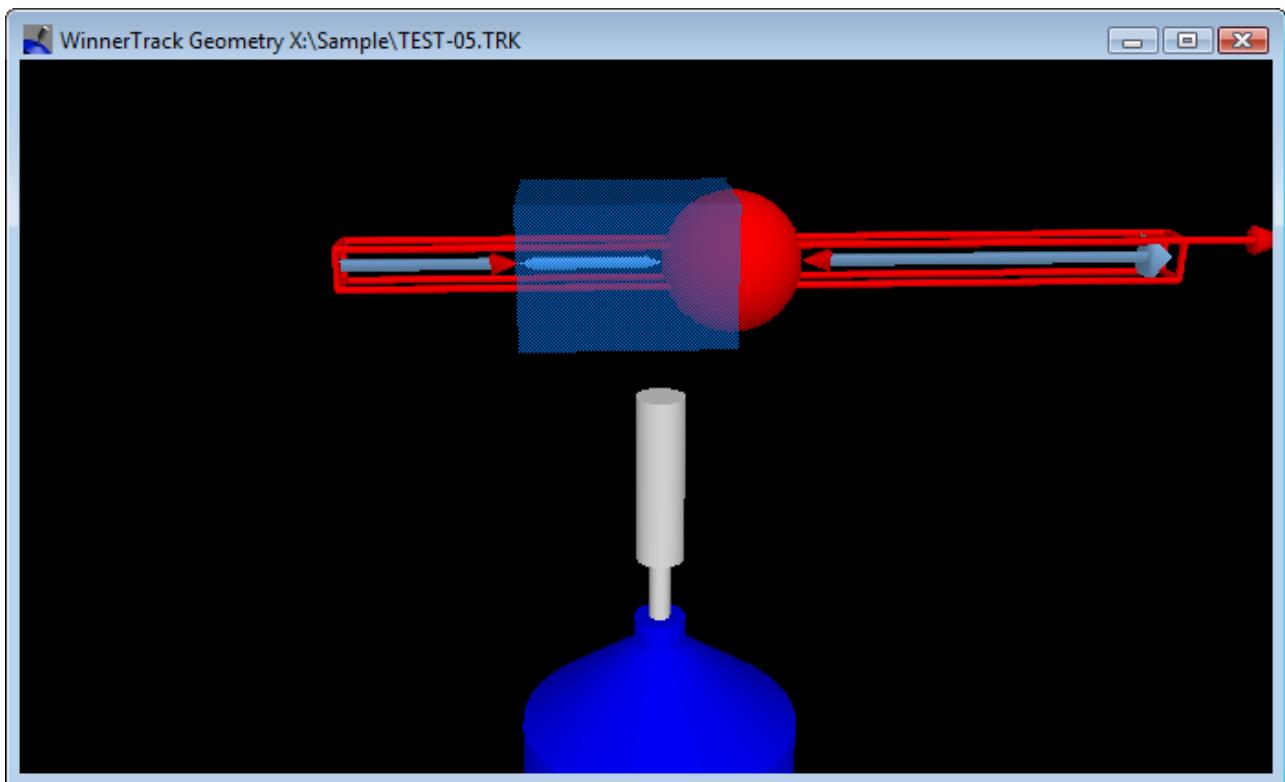
Those test beams are positioned in the scene by the user. They show in graphical and in tabular form where they interact with which object. Test beams are only a test tool. The efficiency calculation is not affected by them.

A test beam is created and positioned into the scene using the usual dialog box.



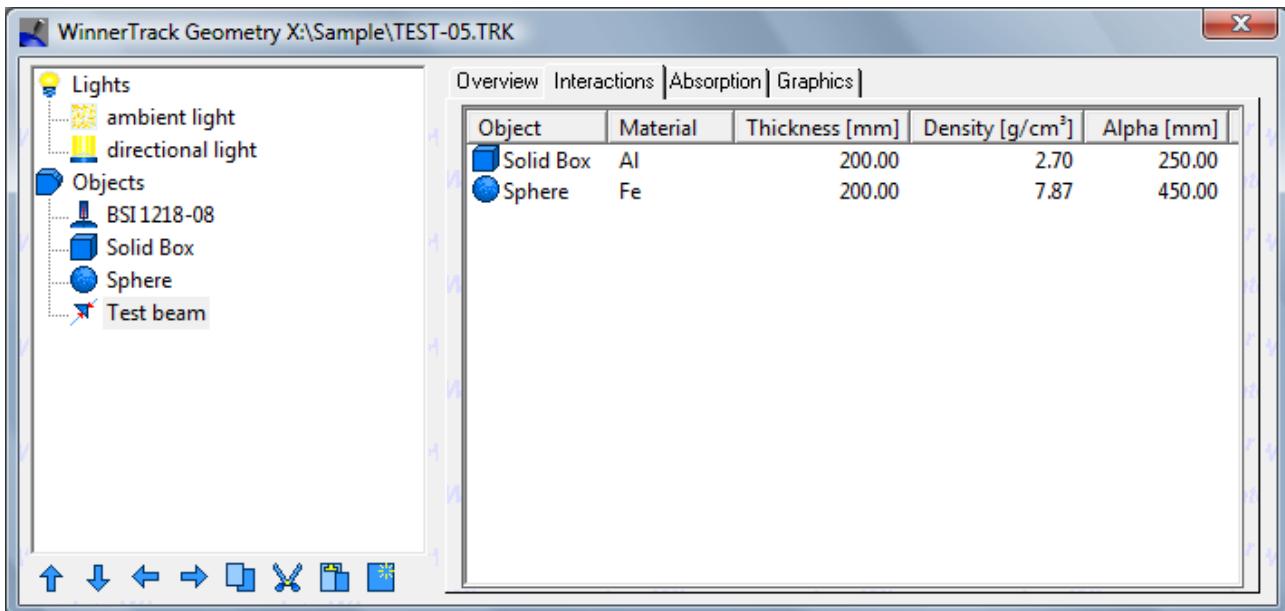
The graphical display will then show the test beam. The points where the test beam enters and leaves an object are marked with small red arrows.

The calculation of the intersection points is made internally and independent of the graphics using the same functions that are used for the analysis. This means that the test beams not only can be used to control the user setup but also are used to check the correctness of the program itself.



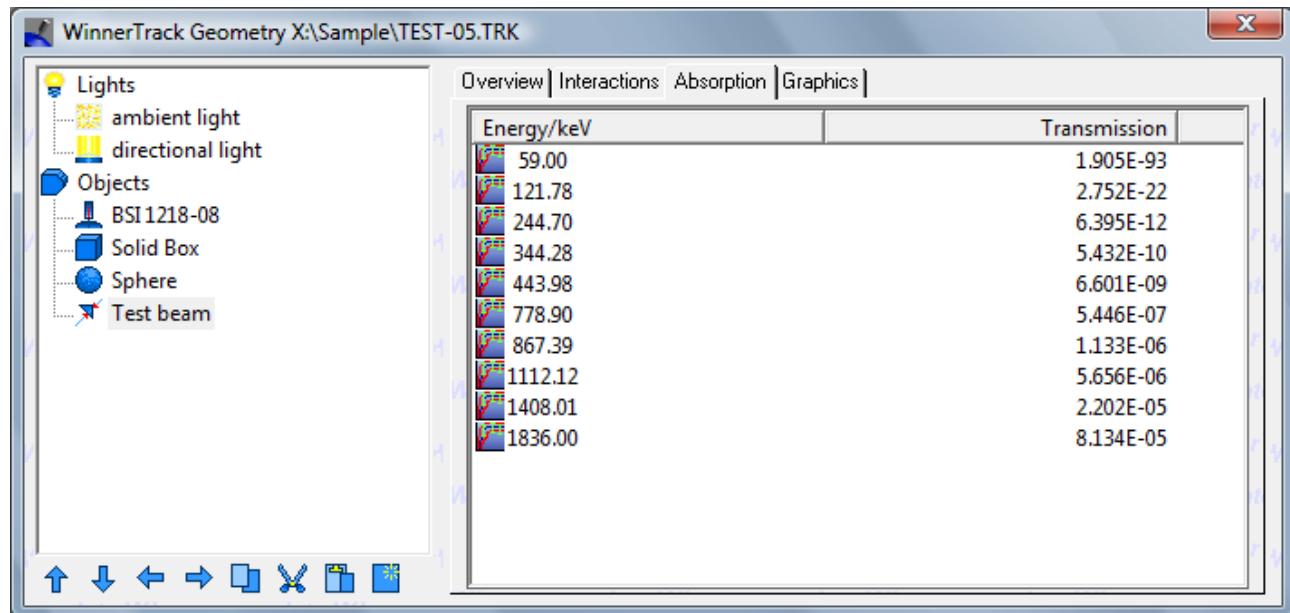
The second page of dialog box, *Interactions*, shows numerically where the interaction points are. In the example one can see that the test beam traveled 250 mm (Alpha=250) before intersecting with an object named “Solid Box” made out of standard density aluminum. The beam traveled 200 mm inside the box (Thicknesses=200) and then hit a sphere made out of iron.

The sphere and the box obviously touch: The sphere is seen at Alpha=450 and the beam traveled inside the box from Alpha=250 to Alpha=250+200=400 mm.

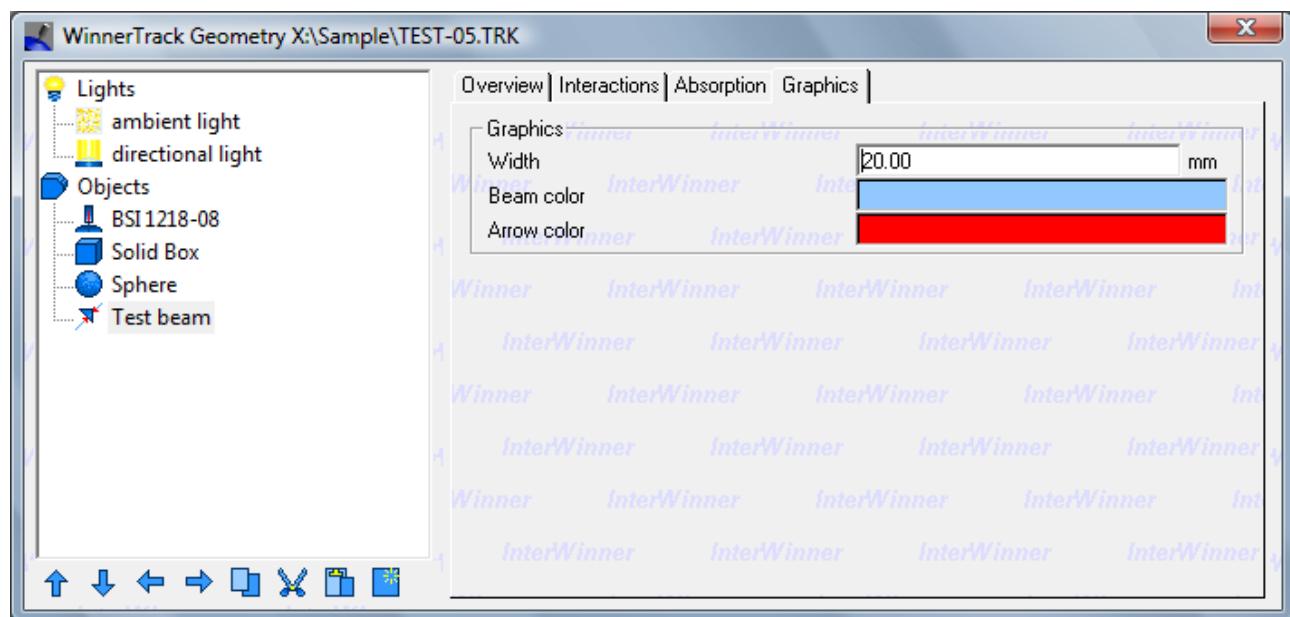


Another page of this dialog box (Absorption) is used to give an estimation of the shielding along the test beams path. The remaining transmission is shown for some frequently used energies.

Please note that this is the full-energy-peak transmission. Energy reduced photons resulting from Compton interactions inside the material are not considered here. These values therefore can't be used for radio protection purposes.

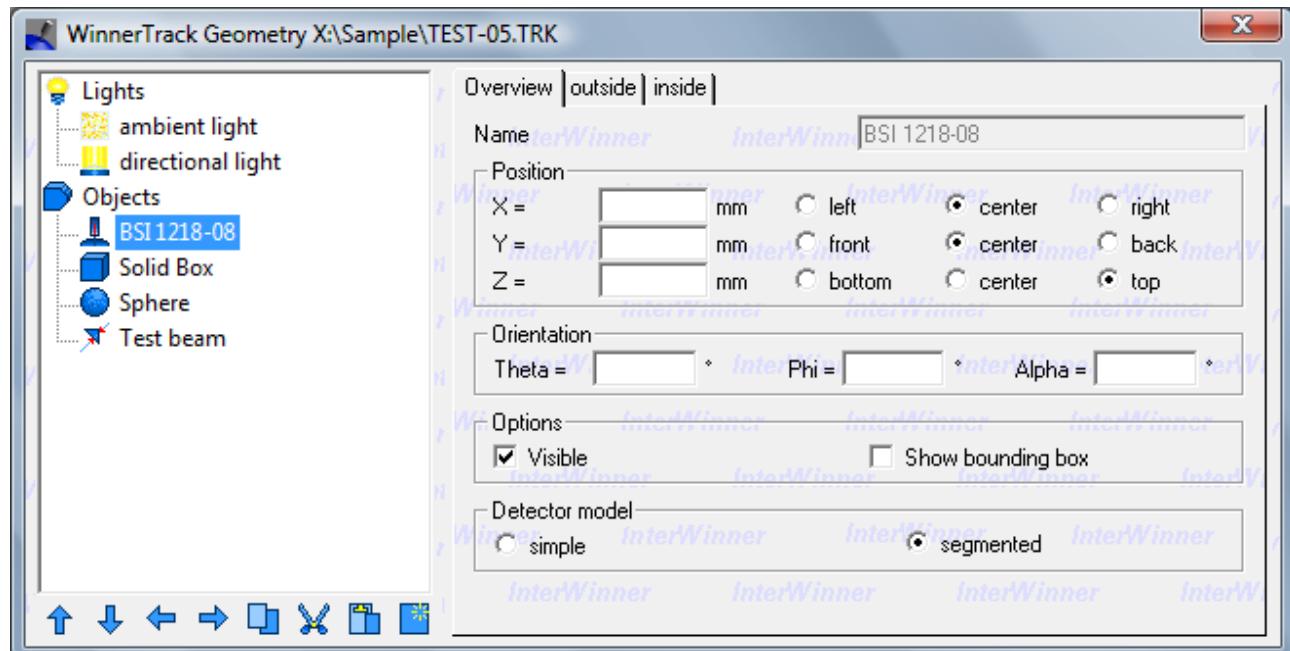


The last page of the dialog box finally shows some display properties of the test beam.



4.6 The detector

If one or several detector characterizations are installed on the system then one can add such a detector to the geometry using the corresponding menu function. The use only has to select the detector and its position and orientation. The inner setup of the detector is entered during the calibration process and can't be modified by the user. It is shown here for illustration purposes only.



One important selection is the selection of the detector model:

The simple model calculates the absorption of the gamma beam between the sample and the detector always by calculating a straight line between sample point and detector crystal center. The advantage of this system is that it calculates very fast. However, the results become wrong if the absorption differs a lot between the paths from a source point to different points of the crystal, for instance when using a collimator or covering half of the detector with a lead brick.

Therefore another detector model is available: In the segmented model the software calculates the absorption in paths to different points of the detector endcap. Those efficiencies are then averaged, weighted with the endcap position dependent efficiency of the detector. This model gives correct results even for small collimators or similar but, of course, takes much longer to calculate.

4.7 *Lightning*

The created scene must contain lights in addition to the real objects. Those lights are used only for the graphical representation and have no influence on the efficiency calculation. There are several types of lights:

Ambient light: This type of light has no position and no orientation. It lights the whole scene with a soft light.

Directional light: This is parallel light. This light has no position but an orientation.

Parallel point light: This light has a defined position and orientation. It is similar to the directional light but has also a position. It can therefore be set in a way that it lights only some objects.

Point light: This light is defined by its position in space. It lights from there into all directions.

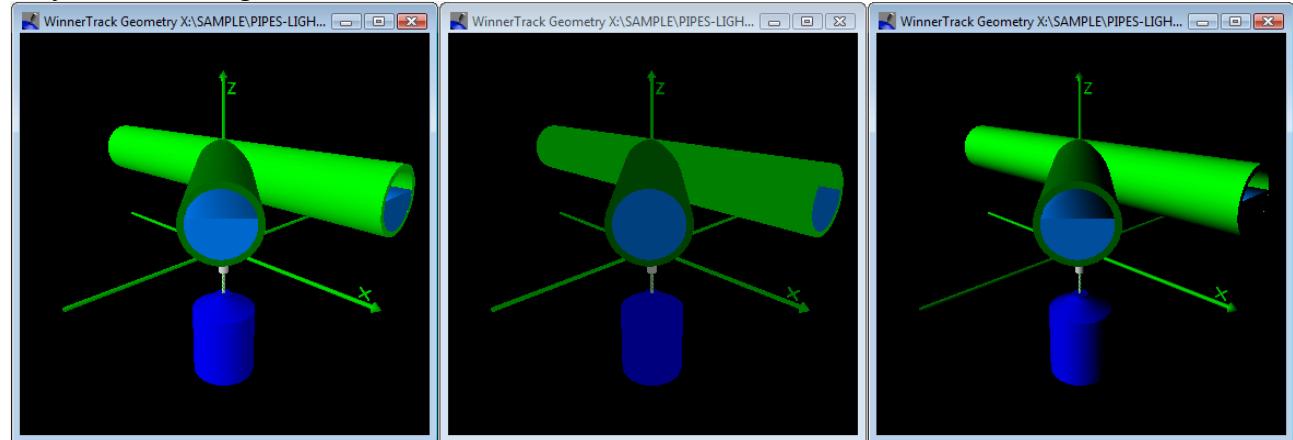
Spot light: This light creates a narrow light cone which starts at the given position and goes into the given orientation.

Generally, one should use at least one ambient and one directed light. Using only directional light will result in totally black shadows. With only an ambient light the scene will loose plasticity, that means that the object three dimensional objects appear flat.

The program automatically adds an ambient and a directional light source when a new file is created.

Please note that the underlying graphics system does not take into account shadows or reflections of the objects.

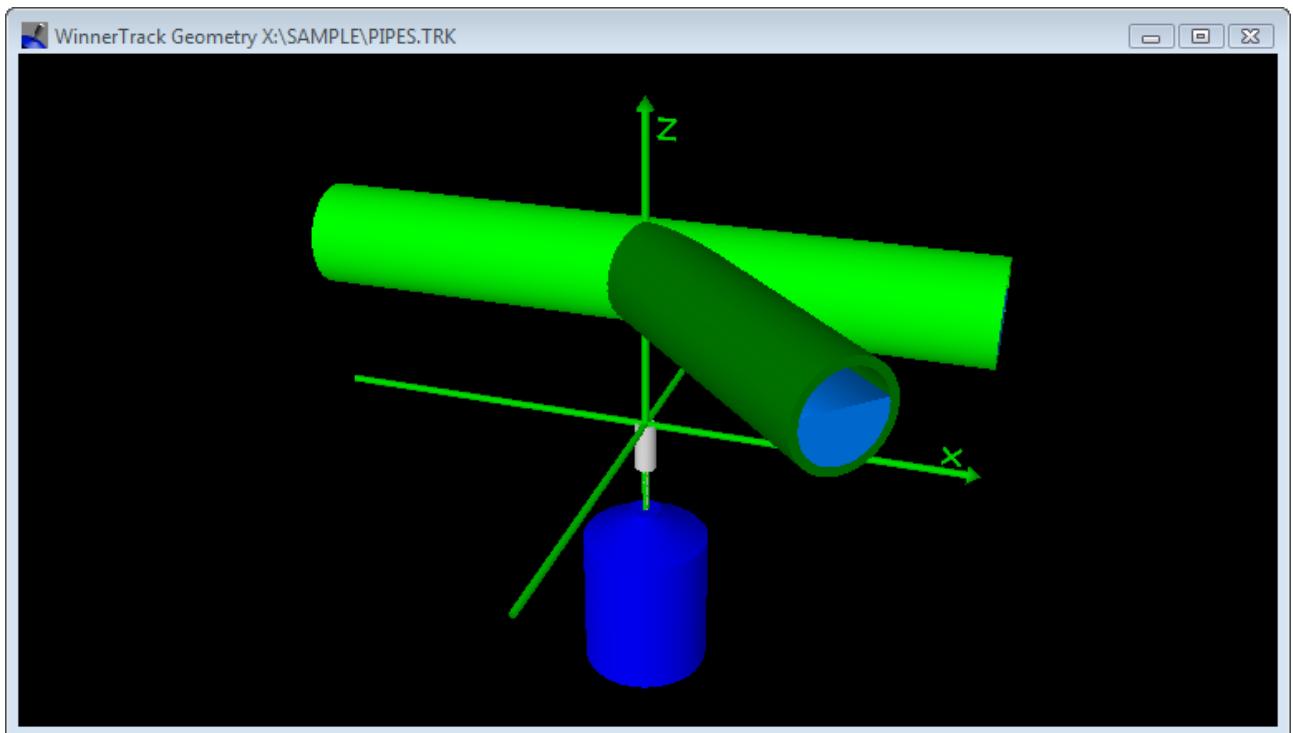
The next figure shows the same scene with ambient and directional light, only ambient light and only directional light.



4.8 Example of a complex geometry

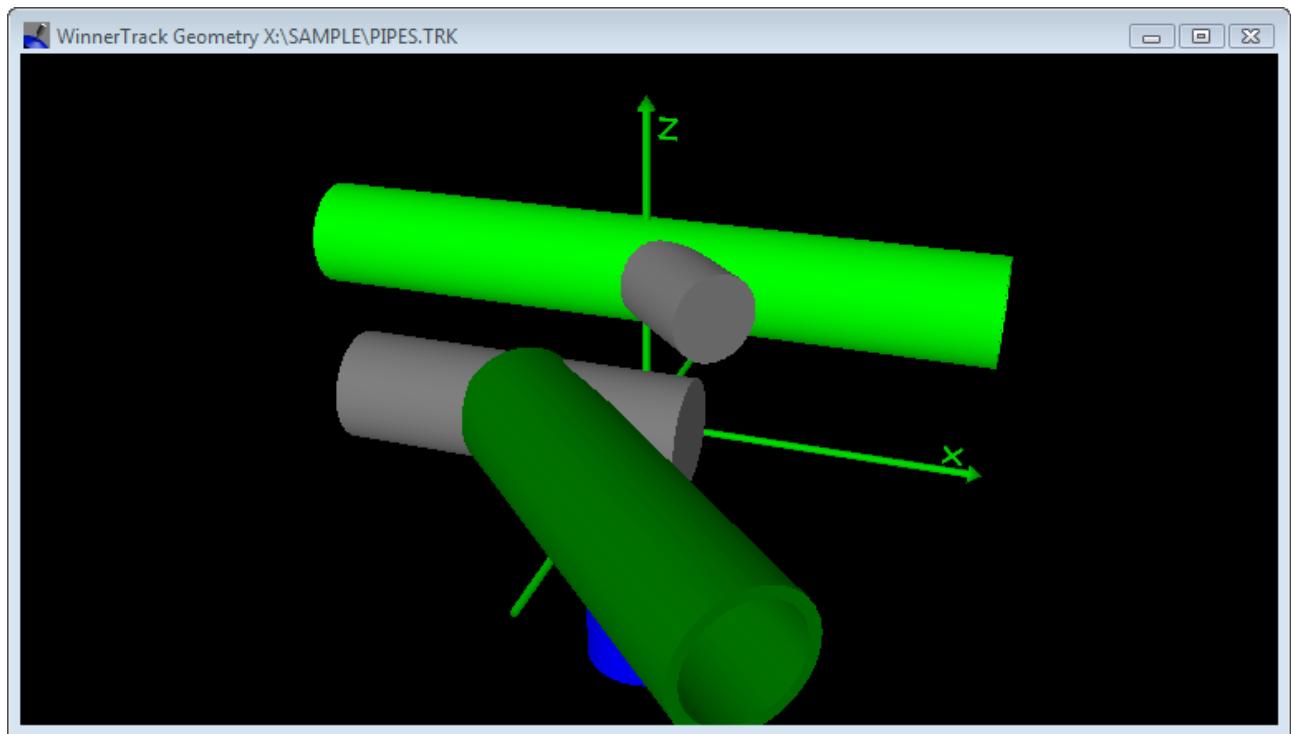
This section shows in an example the setup of a complex geometry. The use of composite and difference objects is shown.

The geometry to build is the connection point of two pipes. Those pipes are partly filled with water or another liquid.

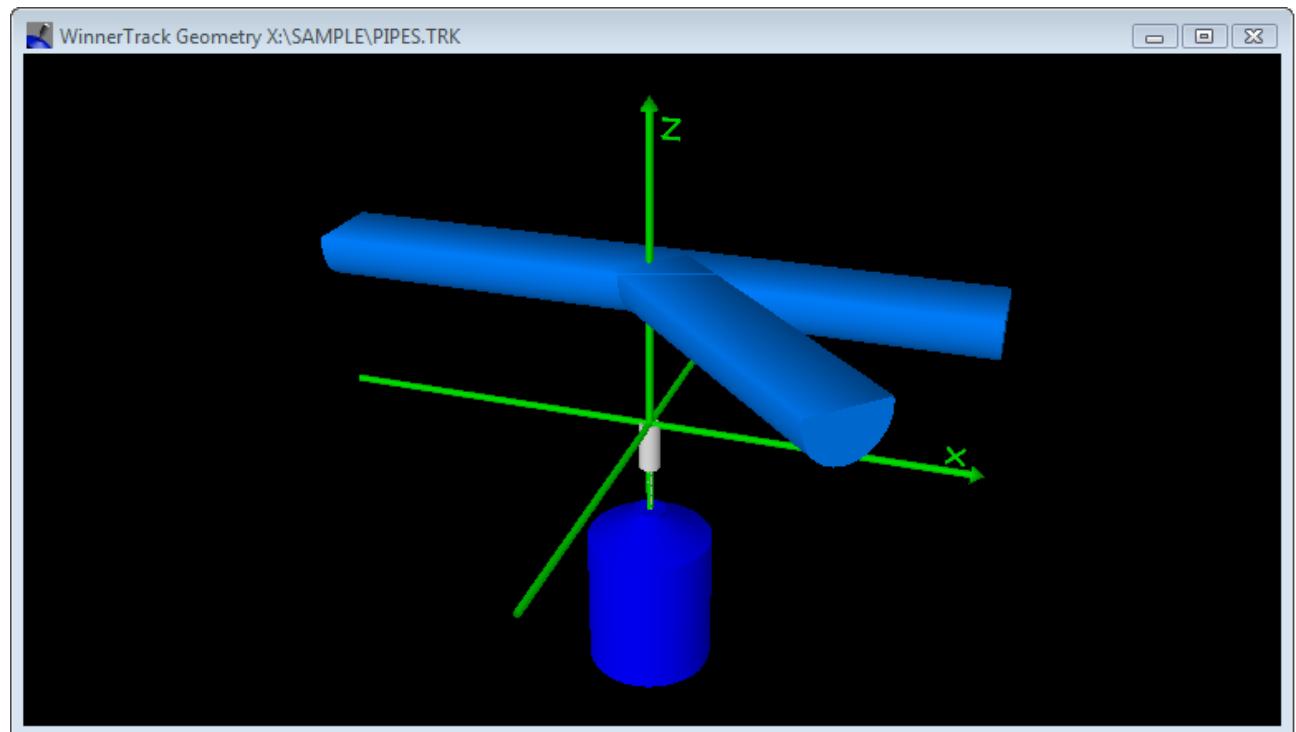


The difficulty is that the pipes are connected to each other. To connect the pipes one needs to drill holes into them – in the real world and also in the simulation.

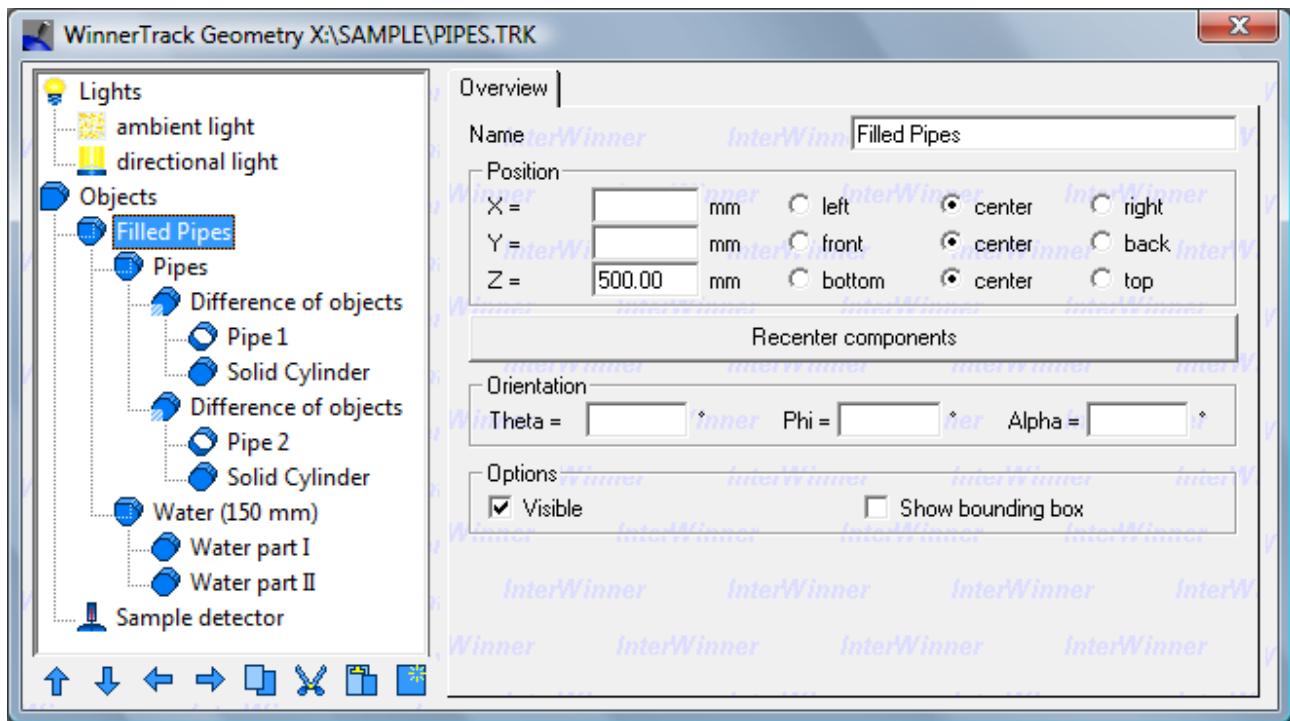
To drill those holes one creates two cylindrical objects which are subtracted from the pipe objects. The pipes are therefore difference objects made out of a pipe minus a cylinder. This is shown in the next figure.



The water will be made out of two *cut cylinder* objects which are assembled in a composite object for easier handling.



Finally, the two pipes and the water are assembled together into one composite object. The next figure shows this assembly hierarchy in the object editor.



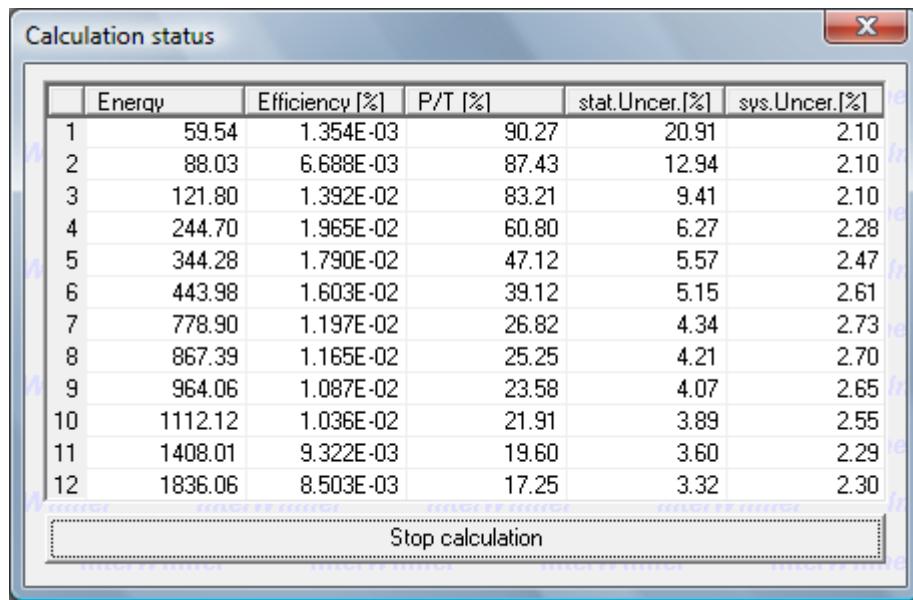
It is recommendable to control the correctness of the created scene using some test beams.

This file is supplied as an example file with InterWinner (file name PIPES.TRK).

5 Calculating the efficiency function

5.1 User interface

The calculation is started after terminating the geometry setup using the entry named *Start Calculation* from the *Edit* menu. The software then loads the characterization files – which may take a few seconds – and then displays a box with the calculation status.



The dialog box is titled 'Calculation status'. It contains a table with 12 rows of data. The columns are labeled: Energy, Efficiency [%], P/T [%], stat.Uncer. [%], and sys.Uncer. [%]. The data is as follows:

	Energy	Efficiency [%]	P/T [%]	stat.Uncer. [%]	sys.Uncer. [%]
1	59.54	1.354E-03	90.27	20.91	2.10
2	88.03	6.688E-03	87.43	12.94	2.10
3	121.80	1.392E-02	83.21	9.41	2.10
4	244.70	1.965E-02	60.80	6.27	2.28
5	344.28	1.790E-02	47.12	5.57	2.47
6	443.98	1.603E-02	39.12	5.15	2.61
7	778.90	1.197E-02	26.82	4.34	2.73
8	867.39	1.165E-02	25.25	4.21	2.70
9	964.06	1.087E-02	23.58	4.07	2.65
10	1112.12	1.036E-02	21.91	3.89	2.55
11	1408.01	9.322E-03	19.60	3.60	2.29
12	1836.06	8.503E-03	17.25	3.32	2.30

At the bottom of the dialog box is a button labeled 'Stop calculation'.

The calculation status box contains the calculated efficiency along with the statistical and systematic uncertainty.

The statistical uncertainty comes from the Monte-Carlo-Integration process. The Monte-Carlo-Integration uses a pseudo-random set of points in the source and calculates the efficiencies for those. The average value taken from this spot check is taken as estimate of the real value. As with any spot check calculation one has a statistical uncertainty calculated using the standard deviation of the measured values and the number of points used. This means that the statical uncertainty becomes smaller as more and more points are calculated.

The systematic uncertainty comes from the characterization uncertainty. It shouldn't change a lot during the calculation.

As soon as the user considers the statistical uncertainty satisfying he can stop the calculation using the corresponding button in the dialog box. The program then opens a dialog box and asks for the name of the efficiency file (.EFF) to be created. The efficiency file is then created and can be used for the analysis of spectra just like an experimentally constructed file.

5.2 User interface for several active objects

If the scene contains several active objects then the global efficiency is the average of the individual objects efficiencies weighted with the relative object activities. The status dialog box reflects this. It can show the global efficiency and relative activity but also the efficiencies and relative activities for the different objects in the scene.

The software tries to minimize calculation time by spending more calculation time on the objects which influence the final result most.

Calculation status					
Object	InterWinner	InterWinner	All		
Activity	InterWinner	InterWinner	InterWinner	InterWinner	InterWinner
1	59.54	9.883E-04	90.32	36.61	2.10
2	88.03	5.505E-03	87.48	23.49	2.10
3	121.80	1.187E-02	83.26	17.00	2.10
4	244.70	1.727E-02	60.84	11.31	2.28
5	344.28	1.581E-02	47.15	10.07	2.47
6	443.98	1.422E-02	39.15	9.33	2.61
7	778.90	1.068E-02	26.83	7.87	2.73
8	867.39	1.040E-02	25.26	7.64	2.70
9	964.06	9.720E-03	23.58	7.39	2.65
10	1112.12	9.264E-03	21.92	7.07	2.55
11	1408.01	8.337E-03	19.61	6.57	2.29
12	1836.06	7.621E-03	17.24	6.04	2.30

5.3 Interactive analysis

In some cases the density or the composition of the measured matrix is not known. It is still possible to make an activity estimation if the sample contains isotopes with several lines. This is done by selecting the matrix in a way that the activity calculated for the different lines of the same isotope are similar or equal.

The software contains an interactive analysis function to do this efficiently. To use this one needs a spectrum of the sample and one should create the geometry setup as far as it is known. Then the corresponding function from the edit menu is selected. The program asks for the spectrum name and starts the calculation immediately. The results are shown in graphical form.

The graphics shows the activities calculated for the different peaks divided by their average. The values should therefore be around one.

If the matrix density or thickness used for the calculation is estimated to high then the software will overestimate the activity. As the absorption is always stronger for low energies the activities calculated using the low energy peaks will be overestimated more, which means that one sees a higher activity in the left part of the graphics. This is shown in the example below.

If the matrix density is underestimated then it will be the other way round: The activities calculated for low-energy peaks will be smaller than the average.

The error bars in the graphics represent the combined error taken from the peak area estimation and from the efficiency calculation. They will therefore become smaller during the calculation.

Changing some parameters of the model (density, material) will restart the calculation. This allows to test different settings rapidly and find the true density using the measured spectrum.

