

How to define a phantom

Any geometry definition is set in square brackets:

[*type* : *commands*]

type defines the geometry type, the details are specified with the *commands*.

The possible types of geometries and the meaning of the commands are explained in the next sections. **All geometry values are zero by default.**

Volume geometries

are needed to define the phantom objects.

Volume geometry types

Volume geometries are used to compose a phantom from objects. The variables *x*, *y* and *z* define (except for cones and tetrahedrons) the object's center of gravity coordinates. Alternatively the object center may be defined by specifying the cartesian vector *center* (*expression*, *expression*, *expression*). All parameters are initialized to zero. Note that all objects can be combined with clip planes (see section [Clip planes](#)).

Sphere

sphere with radius *r*.

Box

box with edges parallel to the coordinate axis and edge lengths *dx*, *dy*, *dz*.

Cylinder_x

cylinder with length *l* and radius *r* parallel to the *x* axis.

Cylinder_y

cylinder with length *l* and radius *r* parallel to the *y* axis.

Cylinder_z

cylinder with length *l* and radius *r* parallel to the *z* axis.

Cylinder

cylinder with length *l* and radius *r*. Vector

axis (*expression*, *expression*, *expression*) defines the (*x*,*y*,*z*)-direction of the axis.

Ellipsoid

triaxial ellipsoid with *half* axis *dx*, *dy*, *dz*; all axes parallel to the coordinate axes.

Ellipsoid_free

triaxial ellipsoid with arbitrary axis directions given by any two of the following vectors forming a mutually orthogonal set:

a_x (*expression*, *expression*, *expression*),

a_y (*expression*, *expression*, *expression*) and

a_z (*expression*, *expression*, *expression*). The two vectors have to be orthogonal but not necessarily normalized. The sizes along these axes are given by the *half* axis lengths *dx*, *dy* and *dz*.

Ellipt_Cyl

cylinder with elliptical cross section, arbitrary orientation in space. Length *l*, half axis *dx*, *dy*. The orientation is defined by any two of the following vectors forming a mutually orthogonal set: *axis* (*expression*, *expression*, *expression*) points in axis direction, *a_x* (*expression*, *expression*, *expression*) defines the direction of the

ellipsoid axis given by dx , $a_y(expression, expression, expression)$ defines the direction of the ellipsoid axis given by dy . The two vectors have to be orthogonal but not necessarily normalized.

Ellipt_Cyl_x

cylinder with elliptical cross section, axis parallel to the x axis, length l , half axis lengths dy, dz .

Ellipt_Cyl_y

cylinder with elliptical cross section, axis parallel to the y axis, length l , half axis lengths dx, dz .

Ellipt_Cyl_z

cylinder with elliptical cross section, axis parallel to the z axis, length l , half axis lengths dx, dy .

Cone

truncated cone, arbitrary orientation in space as given by the axis $axis(expression, expression, expression)$. Length l , radii $r1$ and $r2$ at the two ends of the truncated cone. Moving along the cone axis in the direction given by $axis$, first the end corresponding to $r1$, then the end corresponding to $r2$ is met. x, y and z define the center of the truncated cone axis.

Cone_x

truncated cone of length l , radius $r1$ at the end with smaller x , radius $r2$ at the end with larger x , axis parallel to the x axis. x, y and z define the center of the truncated cone axis.

Cone_y

truncated cone of length l , radius $r1$ at the end with smaller y , radius $r2$ at the end with larger y , axis parallel to the y axis. x, y and z define the center of the truncated cone axis.

Cone_z

truncated cone of length l , radius $r1$ at the end with smaller z , radius $r2$ at the end with larger z , axis parallel to the z axis. x, y and z define the center of the truncated cone axis.

Tetrahedron

tetrahedron with the four corners given by the (x,y,z) vectors

$p1(expression, expression, expression)$,

$p2(expression, expression, expression)$,

$p3(expression, expression, expression)$ and

$p4(expression, expression, expression)$. x, y, z are meaningless. Note that every polyhedron can be composed of tetrahedrons. Another way to create *convex*

polyhedrons is to treat some object (e.g. a sphere) with clip planes (see section [Clip planes](#)).

Clip planes

All volume geometries can be combined with one or several **clip planes**. These clip planes remove parts of the object not contained in the half-space defined by the plane. Clip planes can be defined in two ways:

- By specifying an inequality of the form

$x < expression$

or

$x > expression$

which excludes all points of the object which do not fulfill the inequality (analog for y, z).

- By specifying the normal of an arbitrary plane and its distance to the origin:

$$r(\text{expression}, \text{expression}, \text{expression}) < \text{expression}$$

or

$$r(\text{expression}, \text{expression}, \text{expression}) > \text{expression}$$

This specification is to be understood as *intersection with the set of all points that obey the equation $\mathbf{r} \cdot \mathbf{n} <(>) a$* , where $\mathbf{n} = \mathbf{v}/|\mathbf{v}|$, \mathbf{v} is the given vector, a is the value of the right hand side expression and ' \cdot ' stands for the scalar product.

Hence, if \mathbf{n} is the normal vector of the clip plane pointing *outside* the relevant region (*inside* the region which is to be cut off), the specification is $r(\mathbf{n}) < \mathbf{n} \cdot \mathbf{p}$, where \mathbf{p} is an arbitrary point in the clip plane.

If several clip planes (of any type) are given, the object is intersected with all given half-spaces.

Sample geometries

Here are a few examples for volume geometry definitions:

Without clip planes:

1. [Sphere: r = 4] creates a sphere of radius 4 cm around the origin,
2. [Box: x = 1 y = 1 z = 2 dx = 2 dy = 2 dz = 4] creates a box of 2*2*4 cm³ with one corner located in the origin,
3. [Cylinder: l=10 r=2 axis(1,1,1)] creates a cylinder of length 10 cm and a diameter of 4 cm centered in the origin and pointing into the (1,1,1) direction,
4. [Tetrahedron: p1(0,0,0) p2(1,0,0) p3(0,1,0) p4(0,0,1)] creates a tetrahedron with the four corners (0,0,0), (1,0,0), (0,1,0) and (0,0,1).

Using clip planes:

1. [Sphere:r=5 x<0 y<0] produces a quarter sphere (negative x and y) with the curvature center in the origin,
2. [Sphere:x=-4 r=5 x>0] produces an object in the shape of a planoconvex lens of thickness 1 cm, the convex part pointing into the positive x direction,
3. [Box:x=0.5 y=0.5 z=0.5 dx=1 dy=1 dz=1 r(1,1,1)<1/sqrt(3)] creates the same tetrahedron as in example 4 by truncating a box,
4. [Sphere:r=100 x>0 y>0 z>0 x<2 y<2 z<4] creates the same box as in example 2 by truncating a sphere.

Surface geometries

are used for detectors, antiscatter grids, etc.

The variables x , y and z define the surface reference point. Alternatively the surface reference point may be defined by specifying the cartesian vector `center(expression,expression,expression)`. The extension of the plane is given relative to this point. *Please note:* this point is always in the detector surface.

Plane_xy

rectangular plane parallel to the xy plane.

Plane_xz

rectangular plane parallel to the xz plane.

Plane_yz

rectangular plane parallel to the yz plane.

Plane

arbitrary rectangular plane. It is defined through any *two* of the following vectors:

`norm(expression,expression,expression)`, the surface normal

`a_x(expression,expression,expression)`, the row direction ("east") and

`a_y(expression,expression,expression)`, the column direction ("north"). The two

vectors have to be orthogonal but not necessarily normalized.

Cylindrical_z

cylindrical geometry, axis parallel to the z axis. Rectangular region on the cylinder surface. The angular extension of the detector is defined relative to the vector from the axis (defined elsewhere) to the surface reference point.

Cylindrical

cylindrical geometry, arbitrary axis given by `axis(expression,expression,expression)`.

Rectangular region on the cylinder surface. The angular extension of the detector is defined relative to the vector from the axis (defined elsewhere) to the surface reference point.

Spherical

spherical cone geometry. The surface reference point is irrelevant.