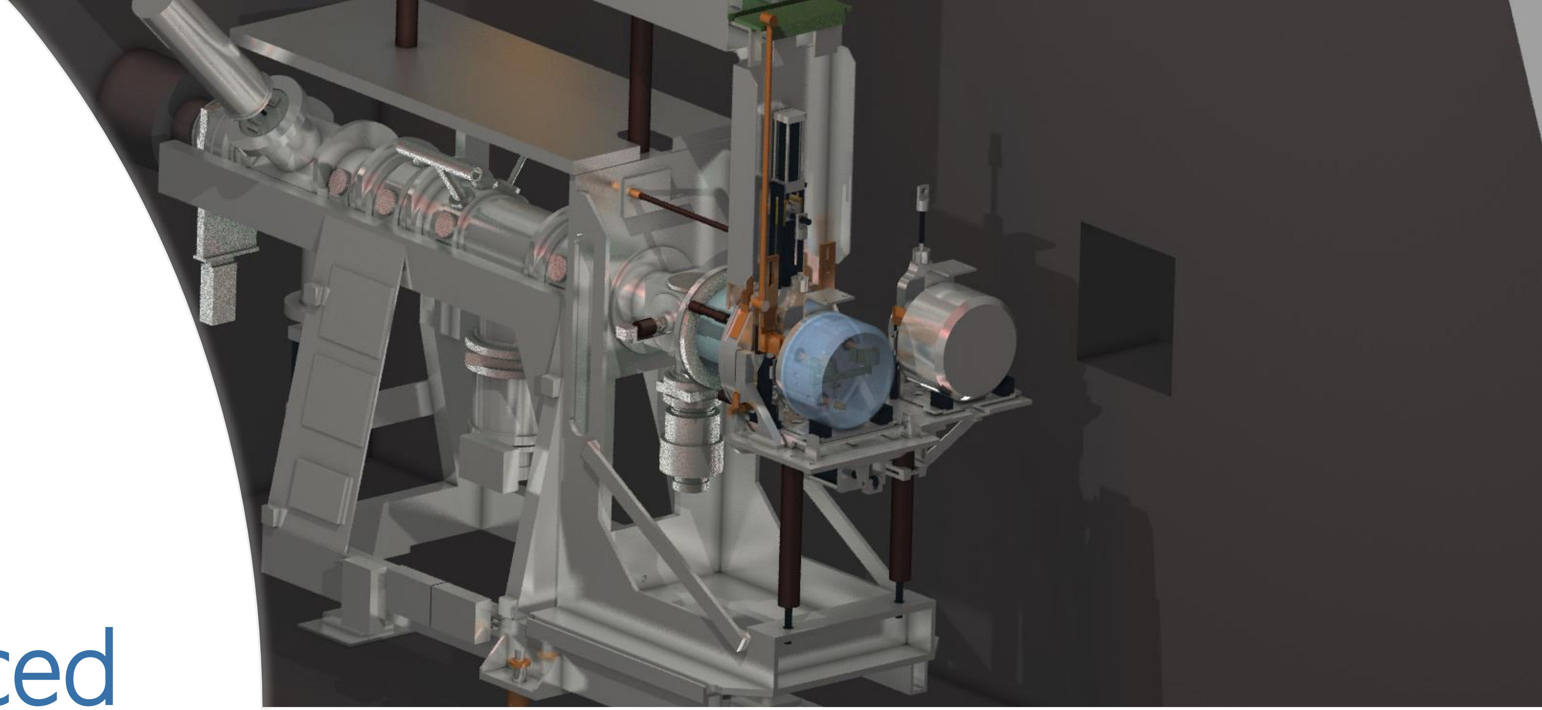
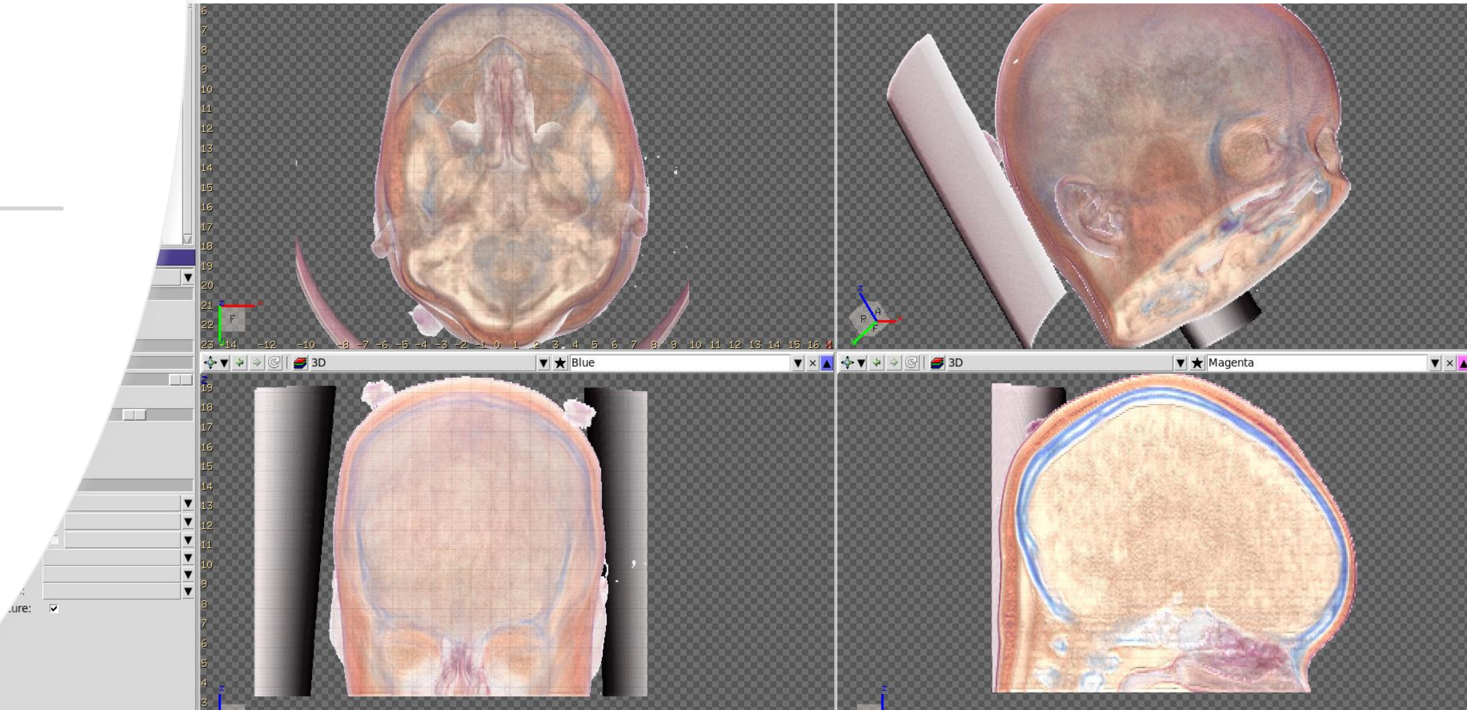
FARM$_{3D}$ – Flair advanced render module

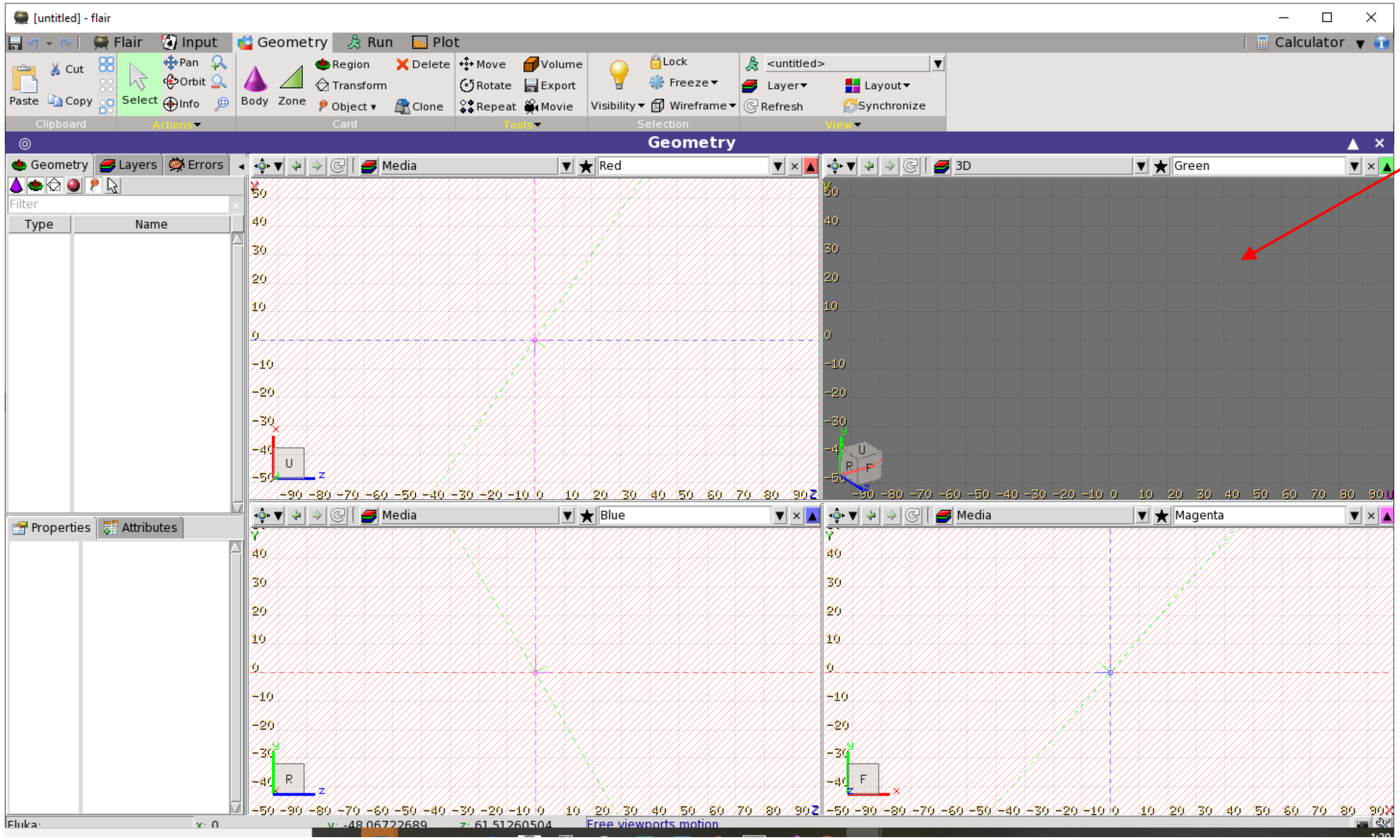
C. Theis, V. Vlachoudis





Introduction

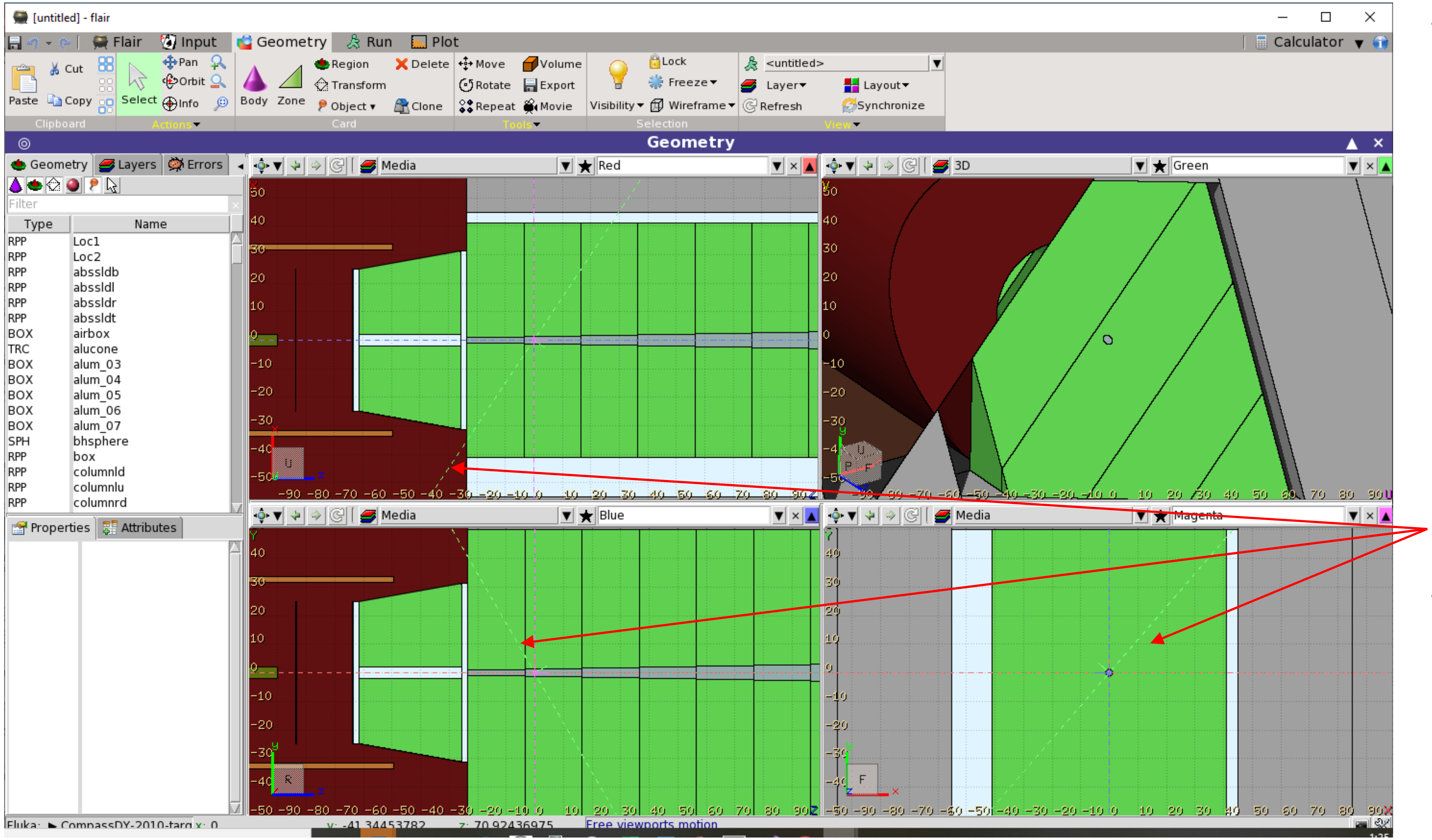
Flair's advanced rendering module offers the possibility to create photorealistic renderings of your geometries in 3D.



By default the 3D view (green) is located in the upper right corner

Introduction

Once you load a geometry you might find yourself with such a view



The 3D view might look “distorted” at first glance. This is due to the fact that for each 2D view there is a plane defining the section and for the 3D view it acts as a clipping plane.

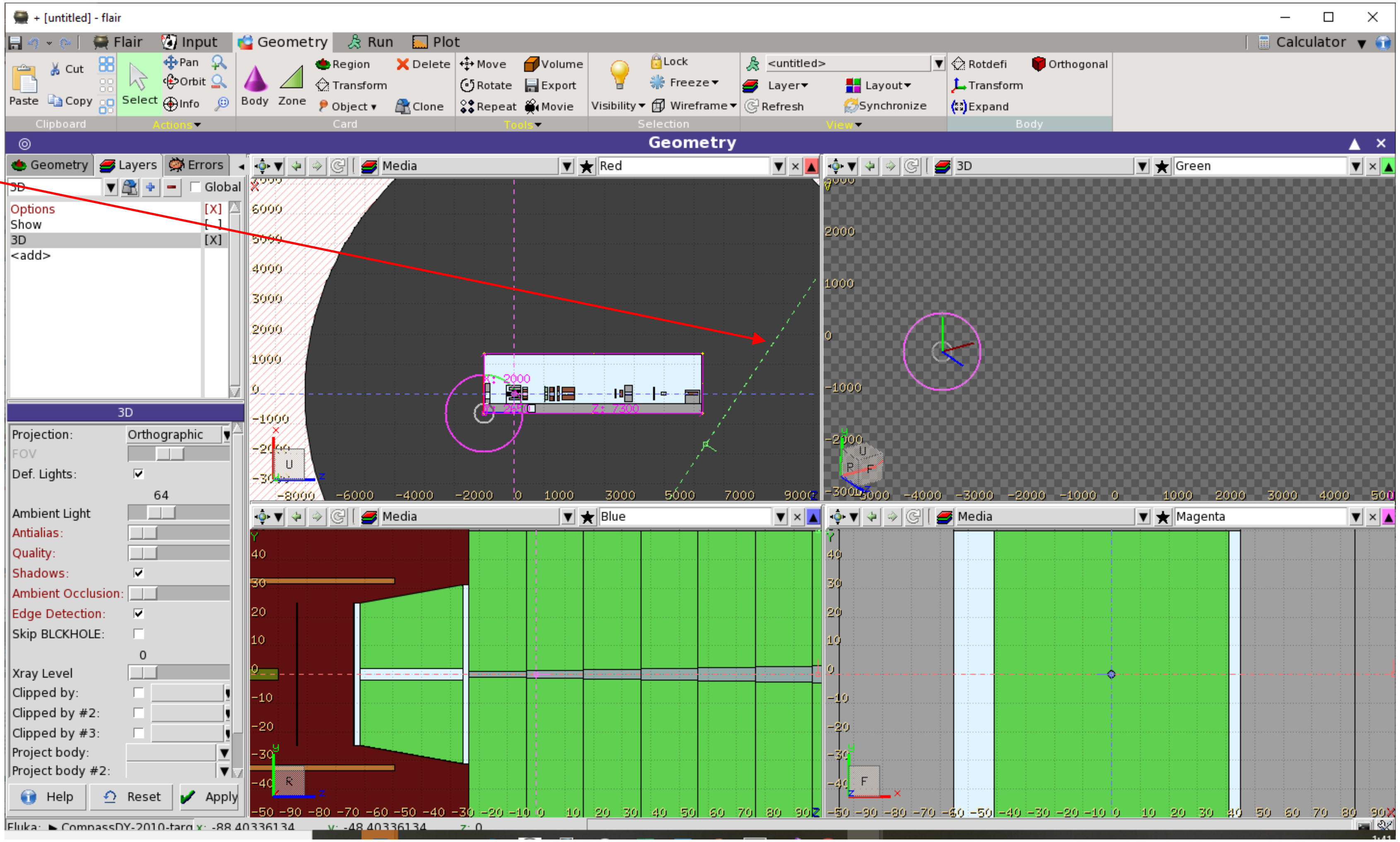
Consequently, every part on the opposite side of that plane will be clipped.

By default it is the “green” plane.

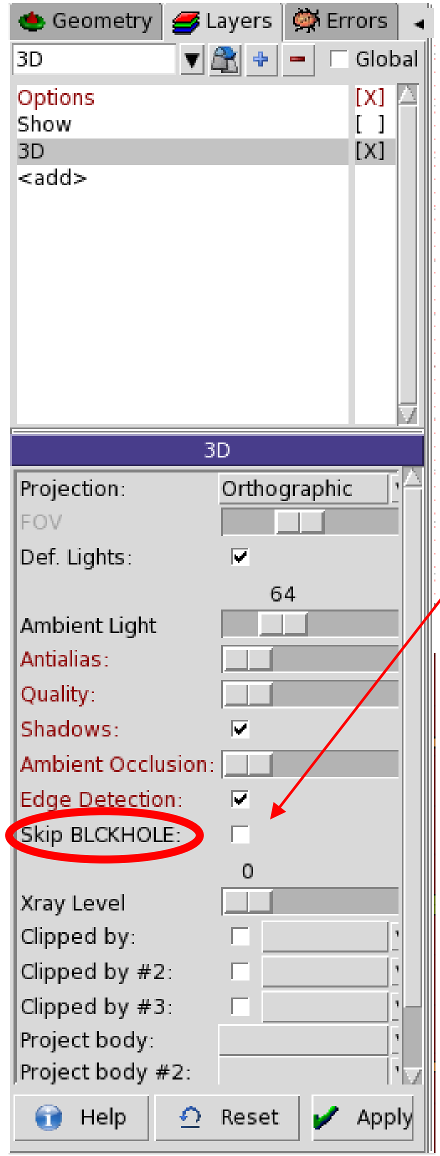
The first thing to do is to move this plane so that no object is clipped anymore and the whole geometry will be shown.

Introduction

When moving the clipping plane the geometry in the 3D view seems to have disappeared because the view is blocked by the “blackhole” surrounding the geometry.



Introduction

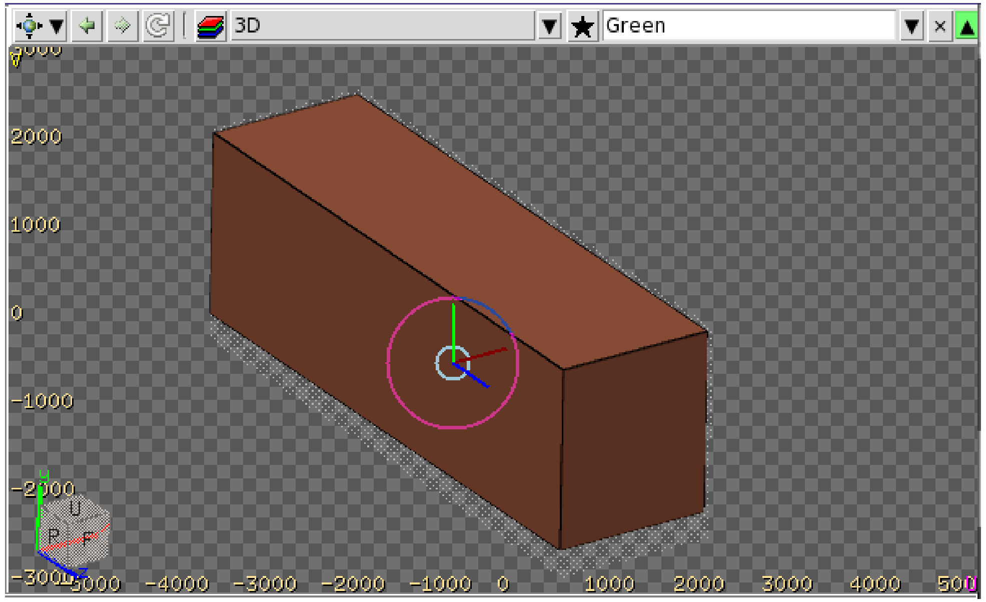


We can make the blackhole disappear by activating the “Layers” tab on the left side of the screen and selecting “3D”.

This will pop up the options of the 3D view which contain a checkbox “Skip BLCKHOLE”.

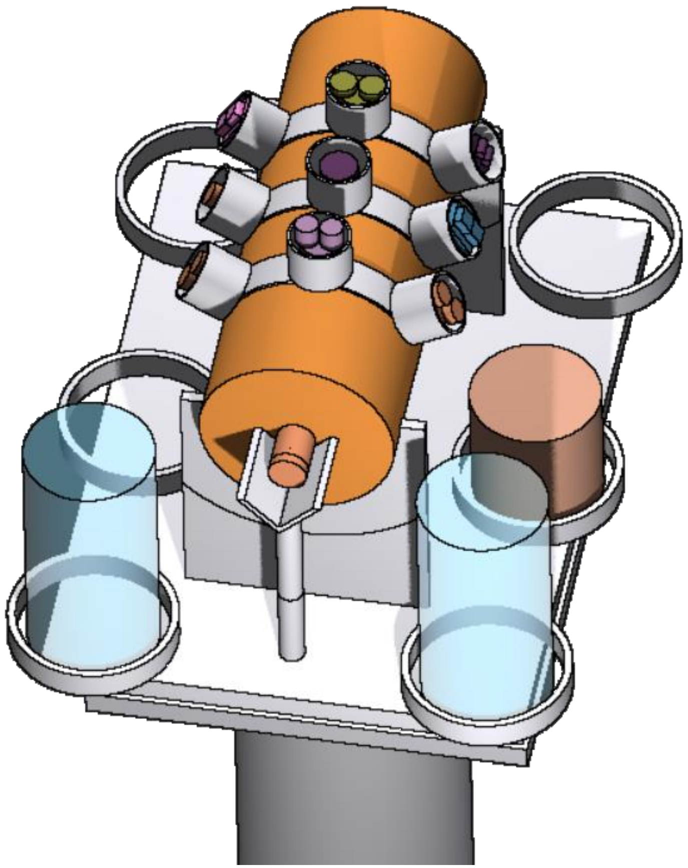
Upon activation the inside part of the geometry will show up.

Transparency can then be set on a region basis (shown later) or per material.

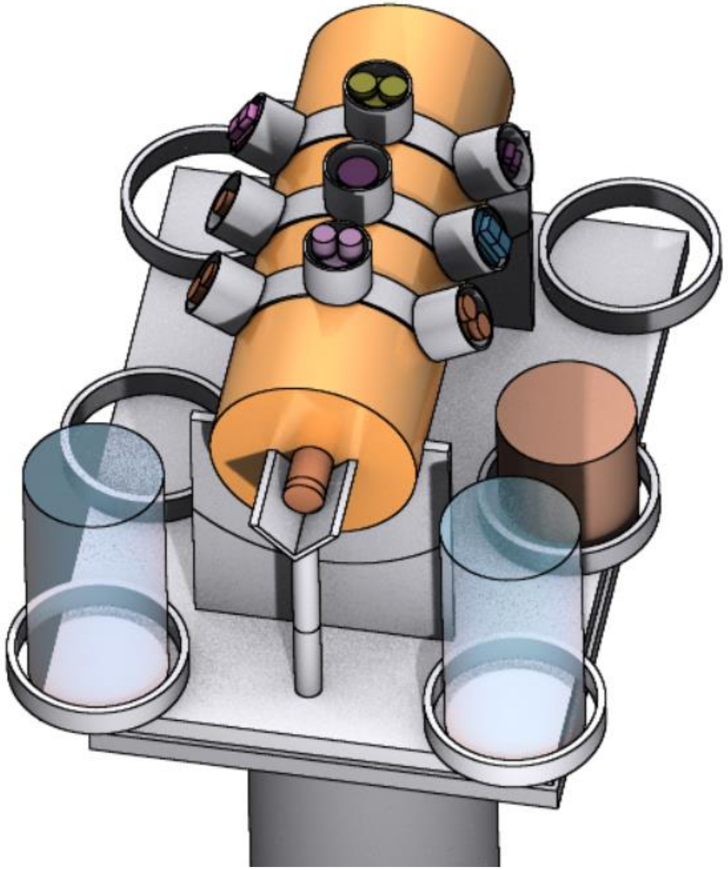


FARM

- Two render modes available
  - Speed – optimized for 3D previews during geometry construction
  - Quality – optimized for high-quality photorealistic renderings for presentations & publications



Speed – interactive rendering

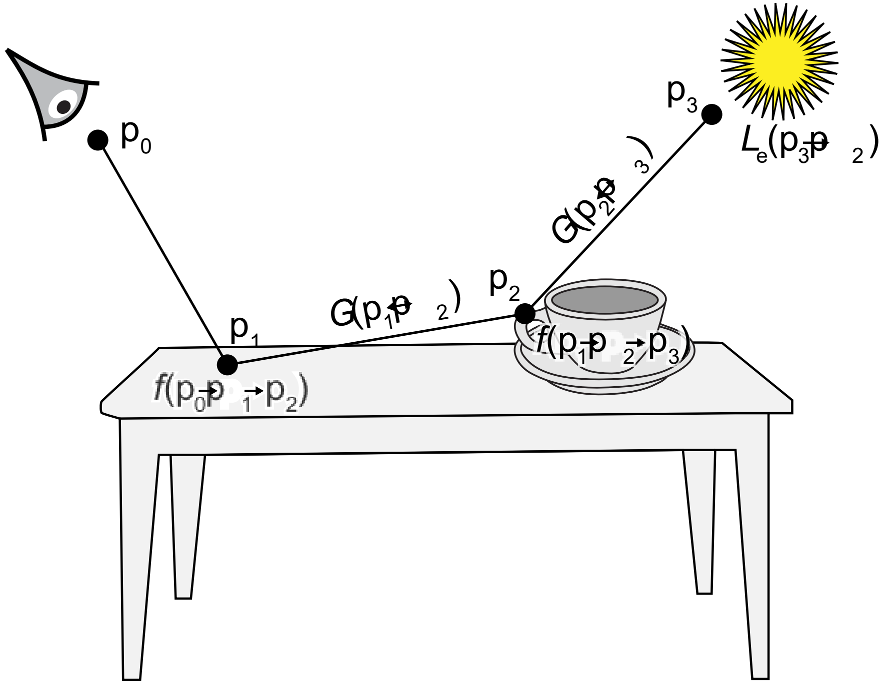


Quality – 15 s to render

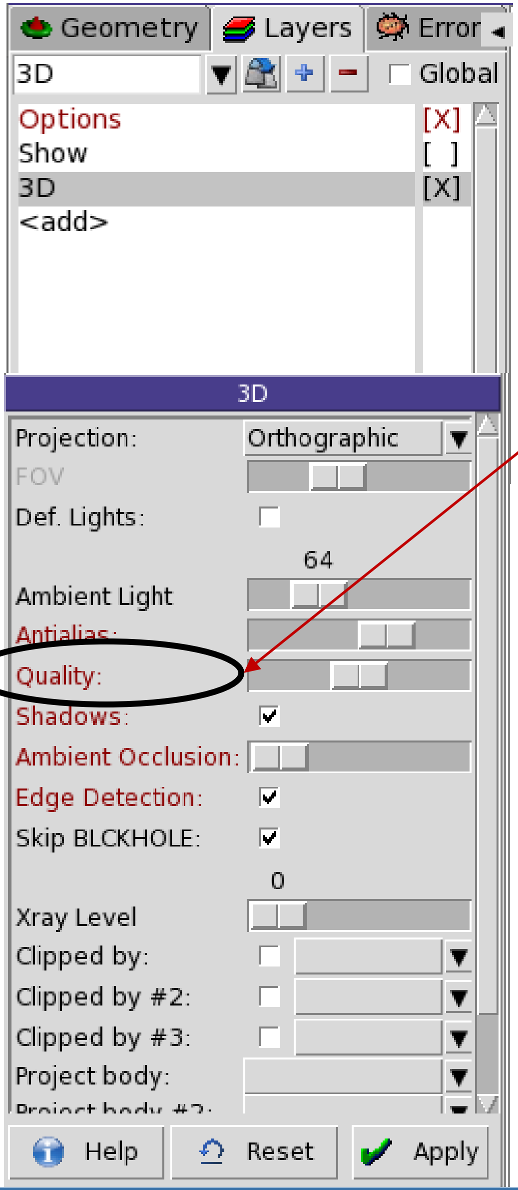
FARM

FARM (Flair advanced rendering module) is a physically based ray-tracer which solves the light transport equation. This is done by integrating so called "bi-direction scattering functions", which model the interaction of photons with material, using Monte Carlo or analytical methods.

In the "Speed" mode it falls back to a relative simplified unphysical lighting model. When activating the "Quality" mode numerous different light interaction models can beselected which are partially based on measured scattering data.



Render - mode



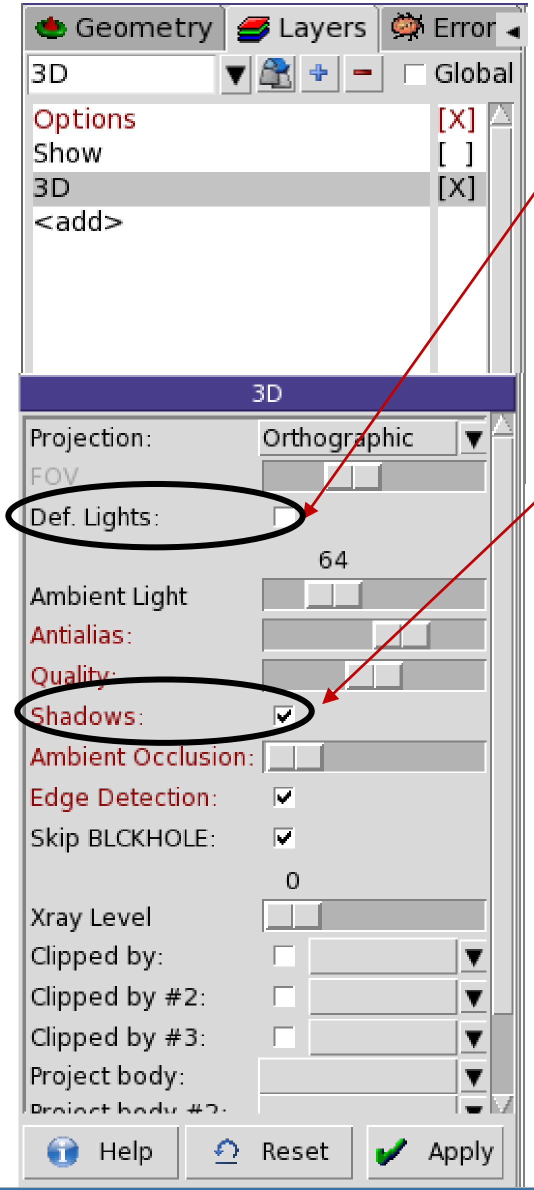
- By default “Speed” mode is activated.
- “Quality” mode can be activated by moving the slider in the 3D layer options to the right

Once “Quality” is enabled the following effects will be taken into account:

- Material dependent scattering & reflection models
- Reflection & refraction of light
- Fresnel reflection for conductors & di-electrics
- Dispersion
- Beer’s absorption
- Microfacet distribution for polished metals

Please note that “Quality” mode is clearly slower as it invokes a physically based renderer requiring more resources to account for all these effects correctly.

Lighting



A set of default lights are activated to ensure proper lighting of the geometry.

These lights act like omni-present sunlight which will be visible as parallel rays of incoming photons. As a consequence so-called hard shadows will be visible, that can be turned-off if needed.

Individual lights can be added as “objects”.

Small light sources however cast soft-shadows as photons are not seen to be coming from a point-like parallel source.

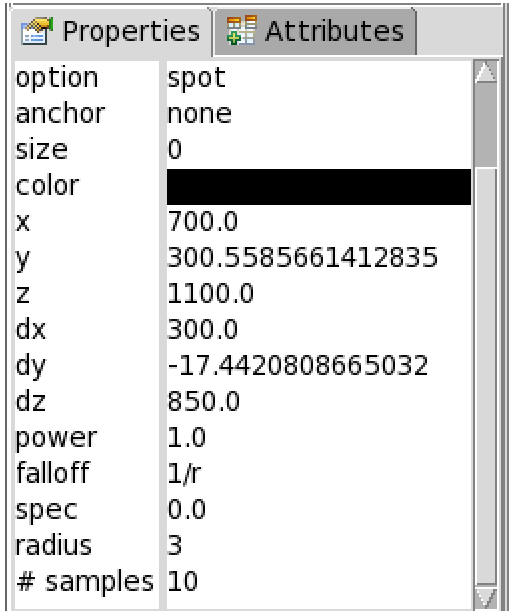
Light sources

Different light sources are available

- Sun light (default = parallel light)
- Directional spot light
- Omni-present light

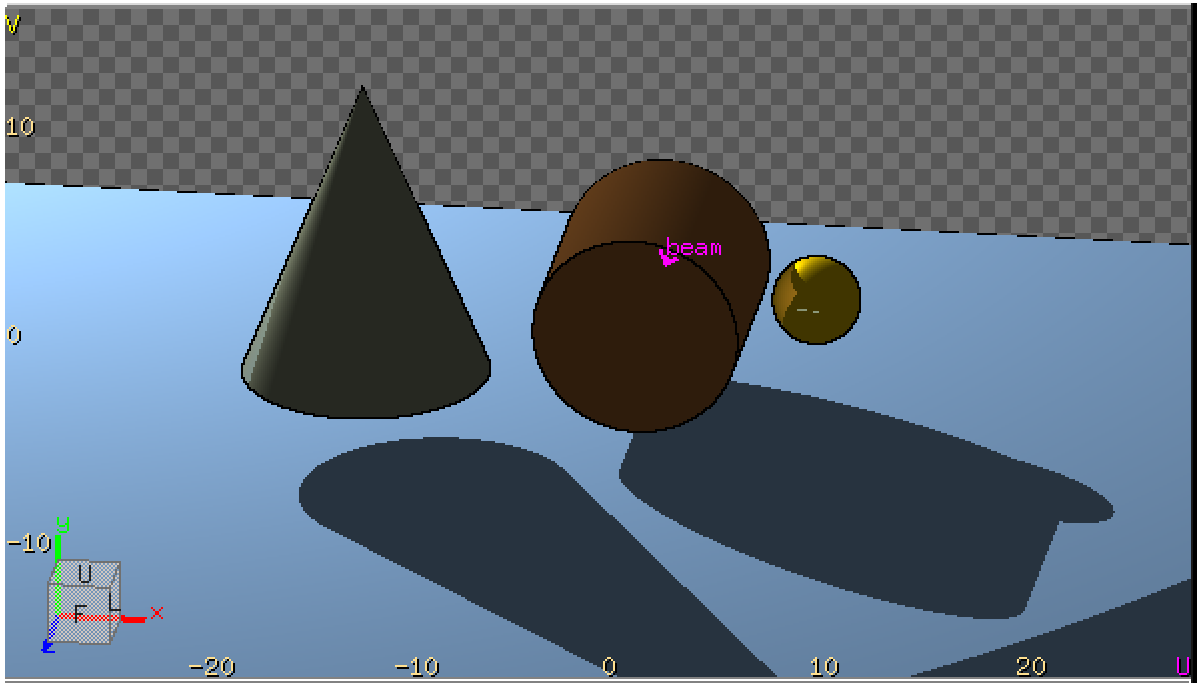
Fall-off can be:

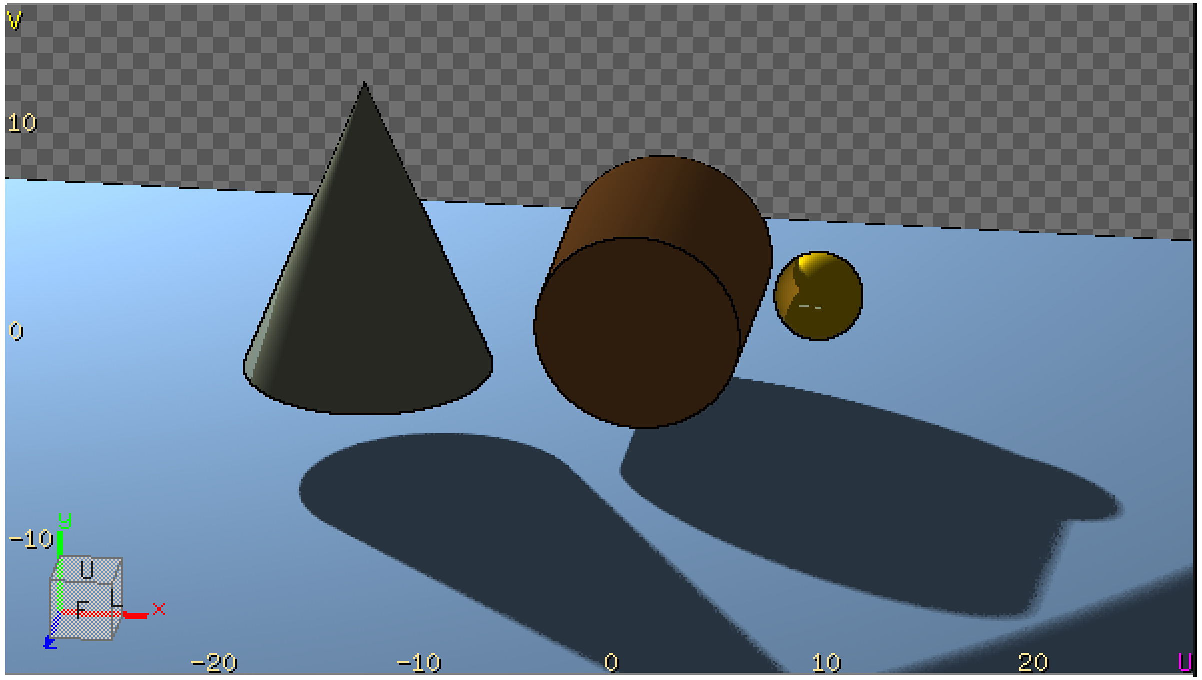
- Constant
- 1/r
- 1/r^2
- With or without casting shadow

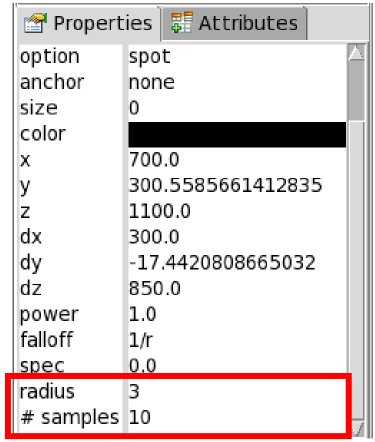


option	spot
anchor	none
size	0
color	
x	700.0
y	300.5585661412835
z	1100.0
dx	300.0
dy	-17.4420808665032
dz	850.0
power	1.0
falloff	1/r
spec	0.0
radius	3
# samples	10

Light sources

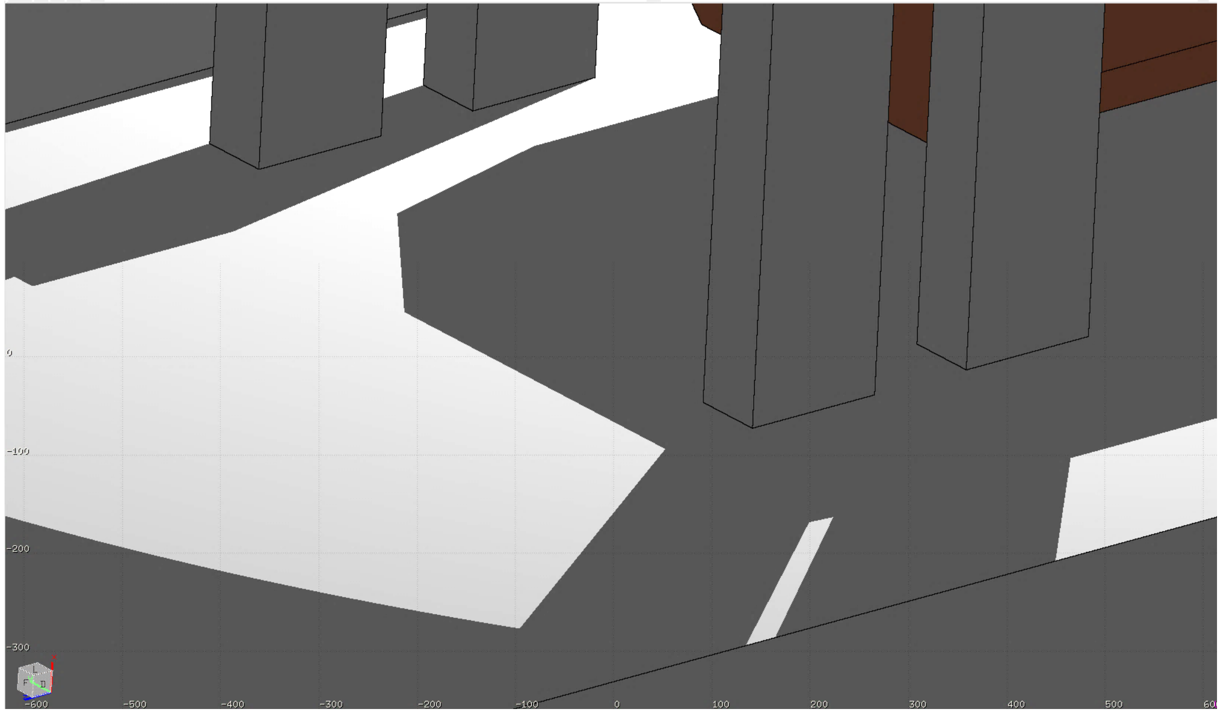




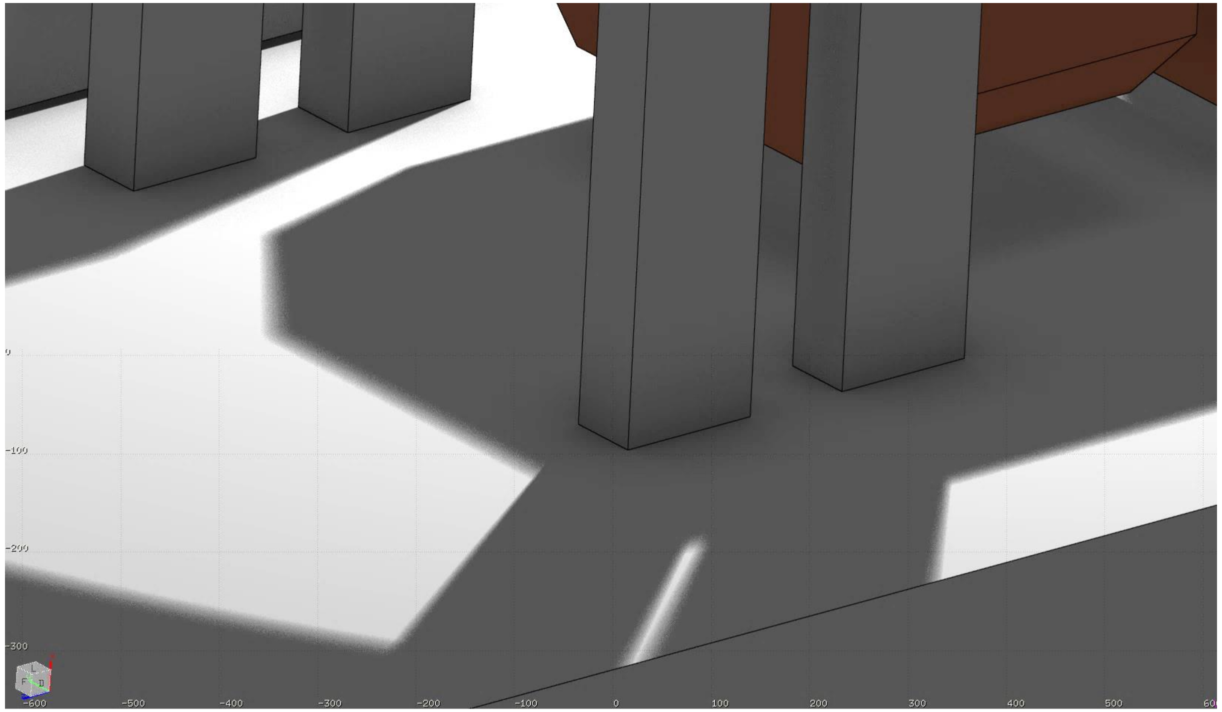


For soft penumbra shadows the light-source must be given a volumetric radius and a number of samples that are used to calculate the penumbra integral.

Light sources & shadows



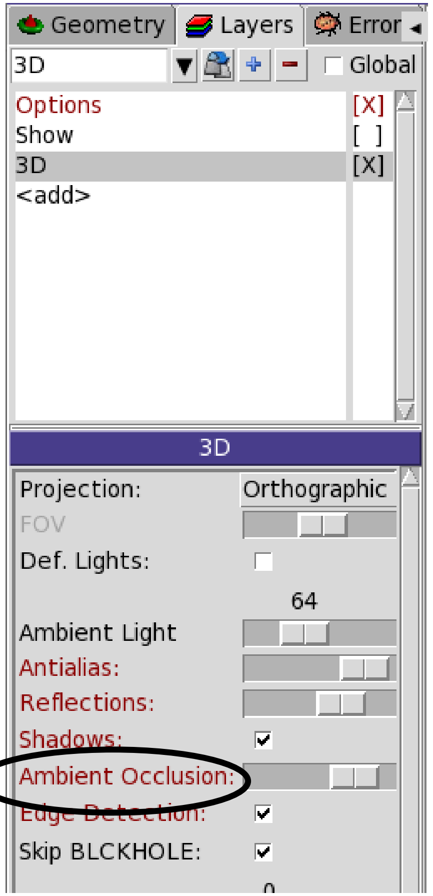
Standard point-source

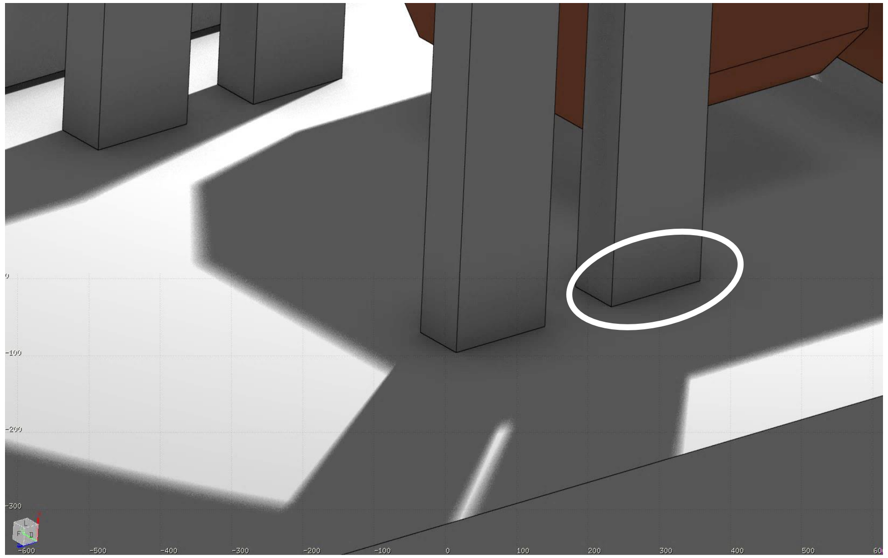


Volumetric light source

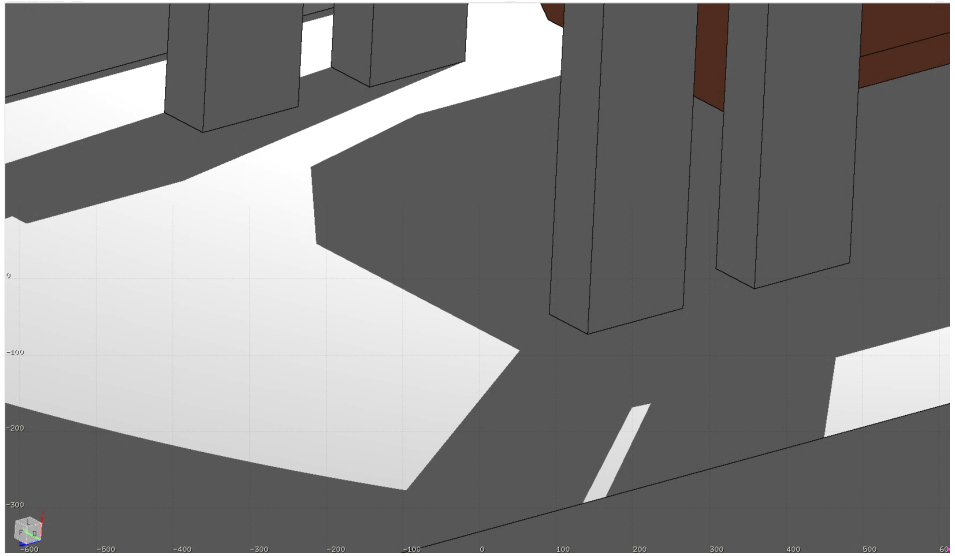
Additional rendering parameters

- Ambient occlusion = absorption of light scattered from neighbouring objects





With ambient occlusion

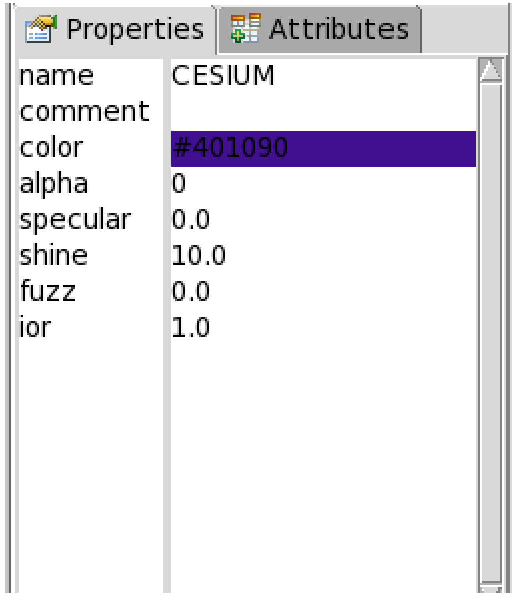


Without ambient occlusion

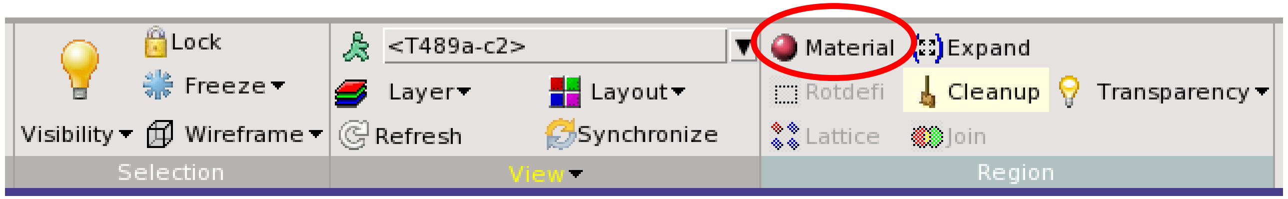
Material parameters

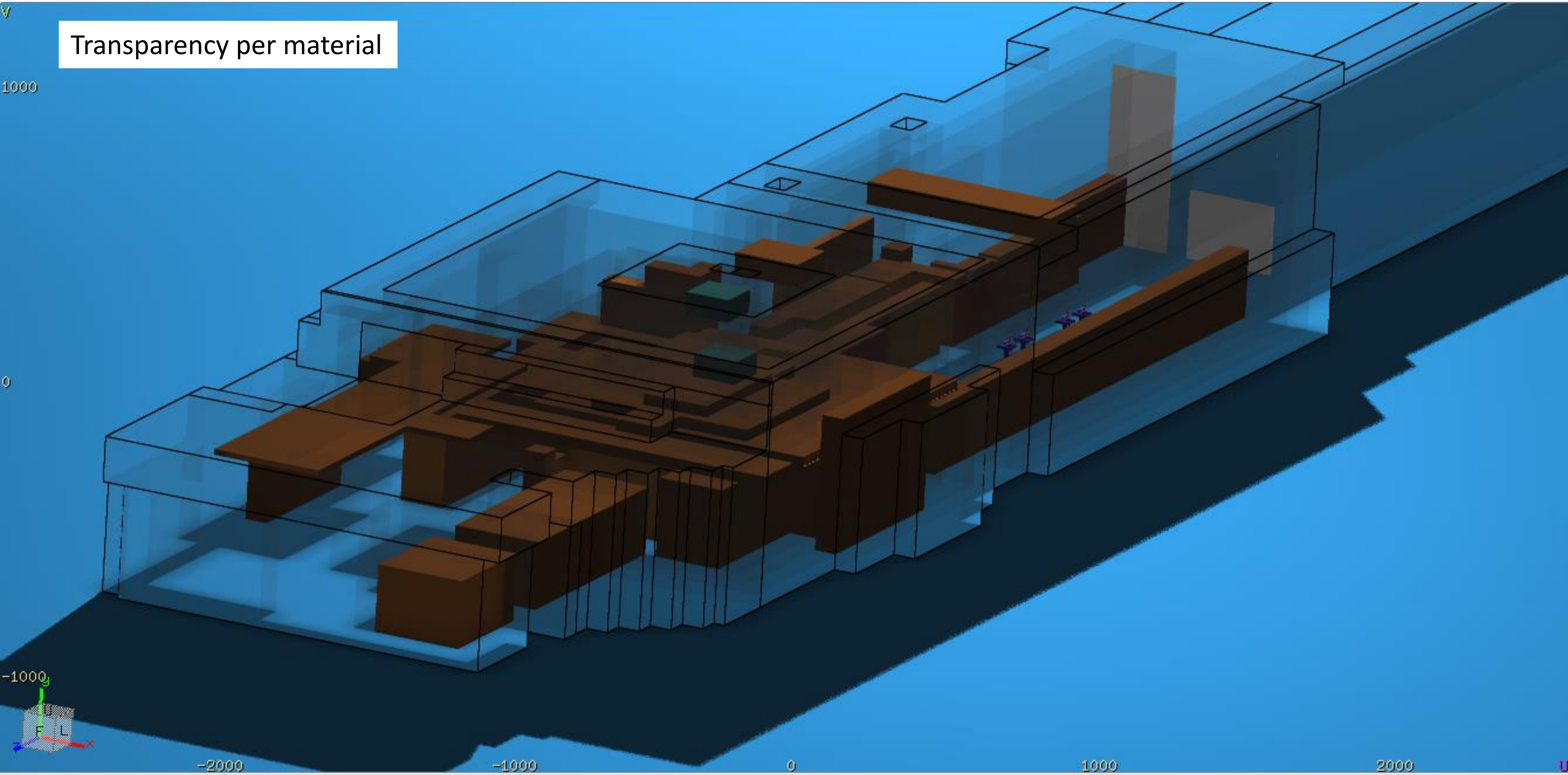
Material properties:

- Alpha = transparency [0, 100]. 0 = opaque
- Specular [0,1] = reflectivity
- Shine [0,100] = specular reflection power
- Fuzz [0,1] = diffuse reflection
- Ior = index of refraction
- BxDF = photon interaction model (e.g. polished metal, substrate, glass, etc.)

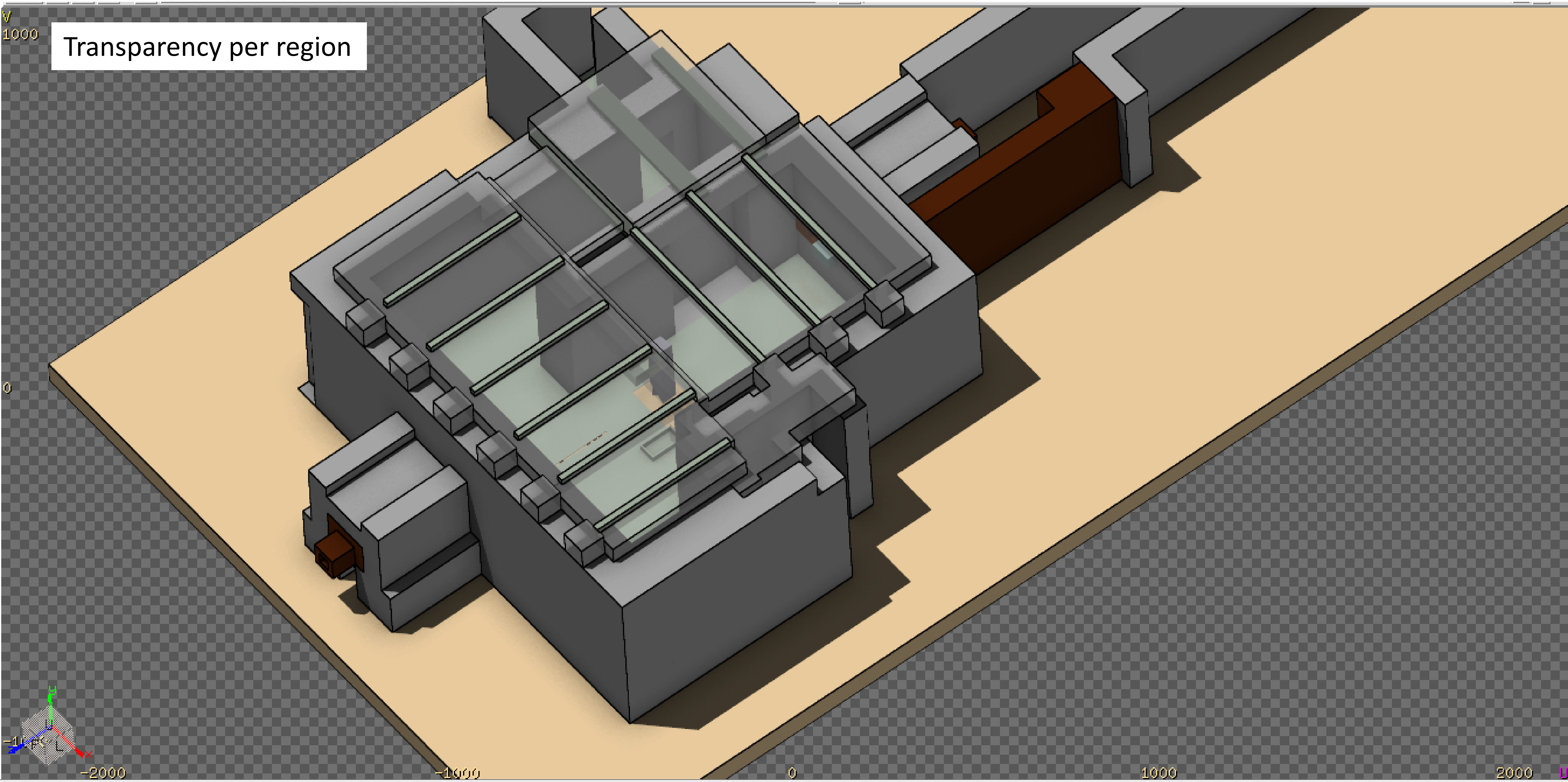


NOTE: For each region the material transparency can be individually overridden by selecting the region and then choosing “transparency” from the top ribbon menu!

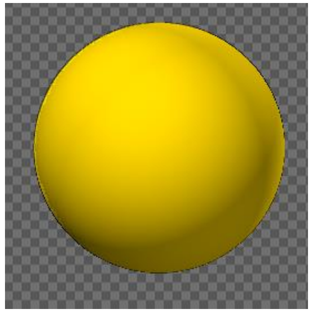
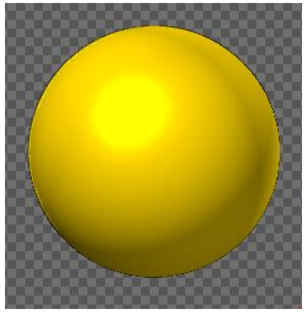
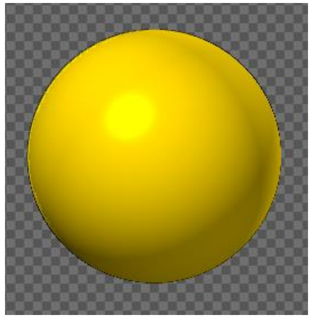
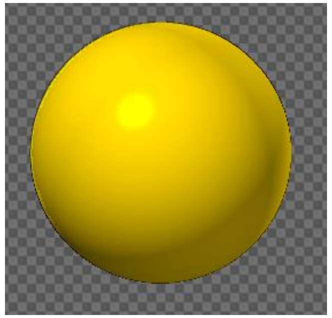



Transparency per material
V
1000
0
-1000
-2000
-1000
0
1000
2000
U

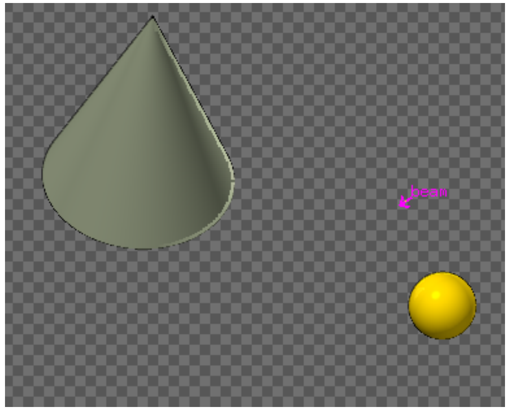
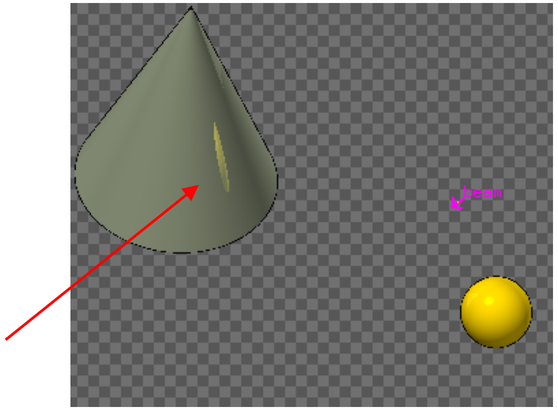
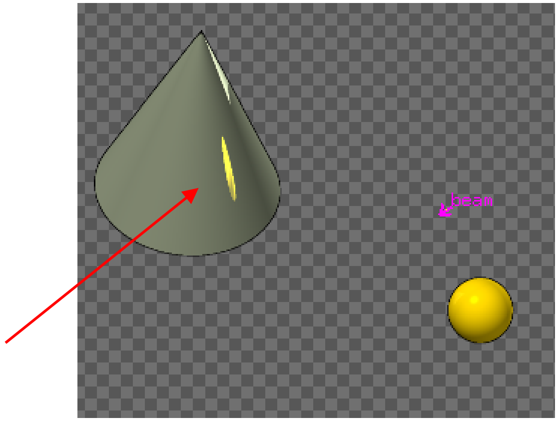
Transparency per region



Material parameters

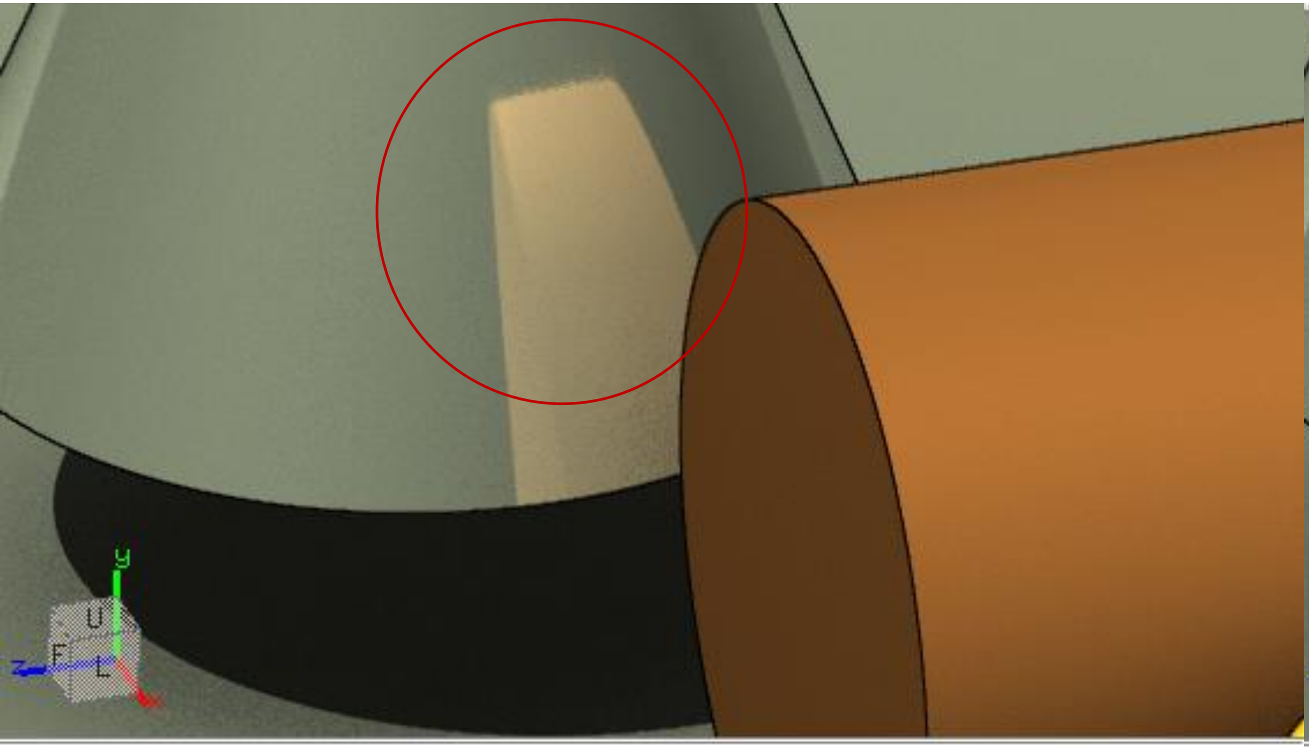
   

Specular 0 30 60 90

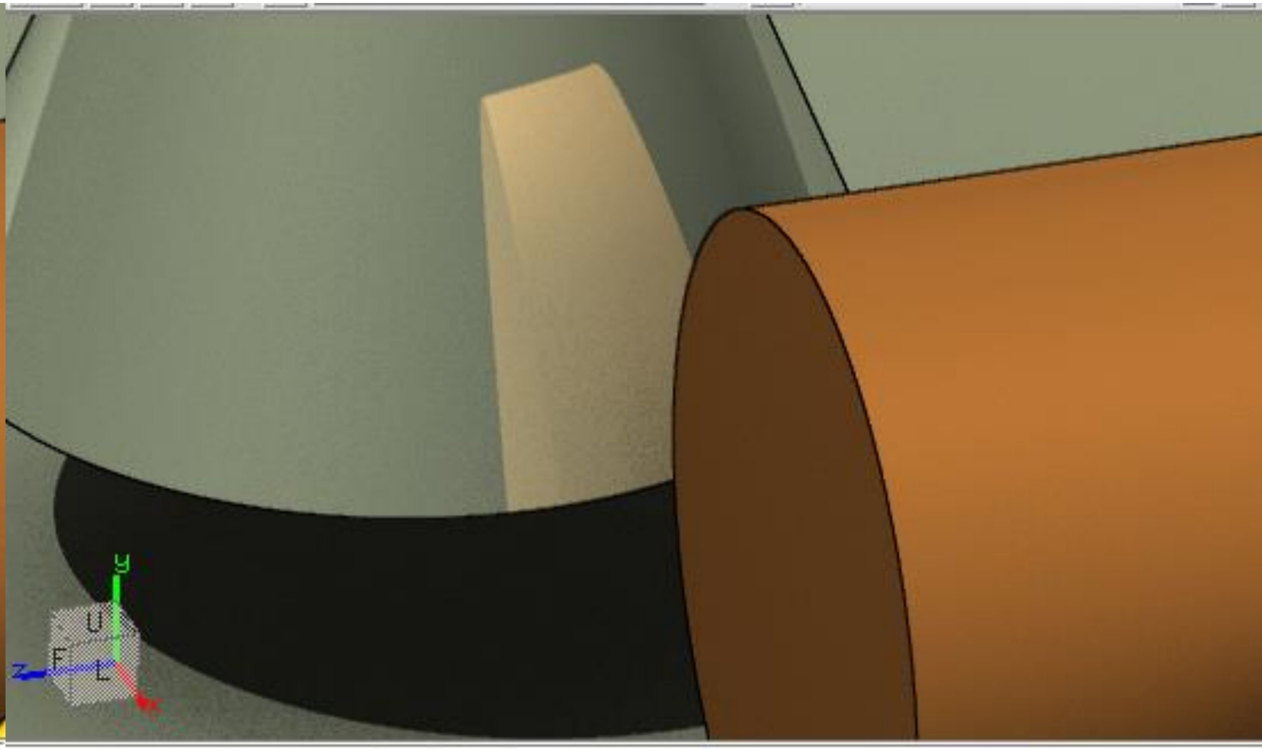
  

Shine 0 0.3 0.8

Diffuse reflection vs perfectly specular reflection

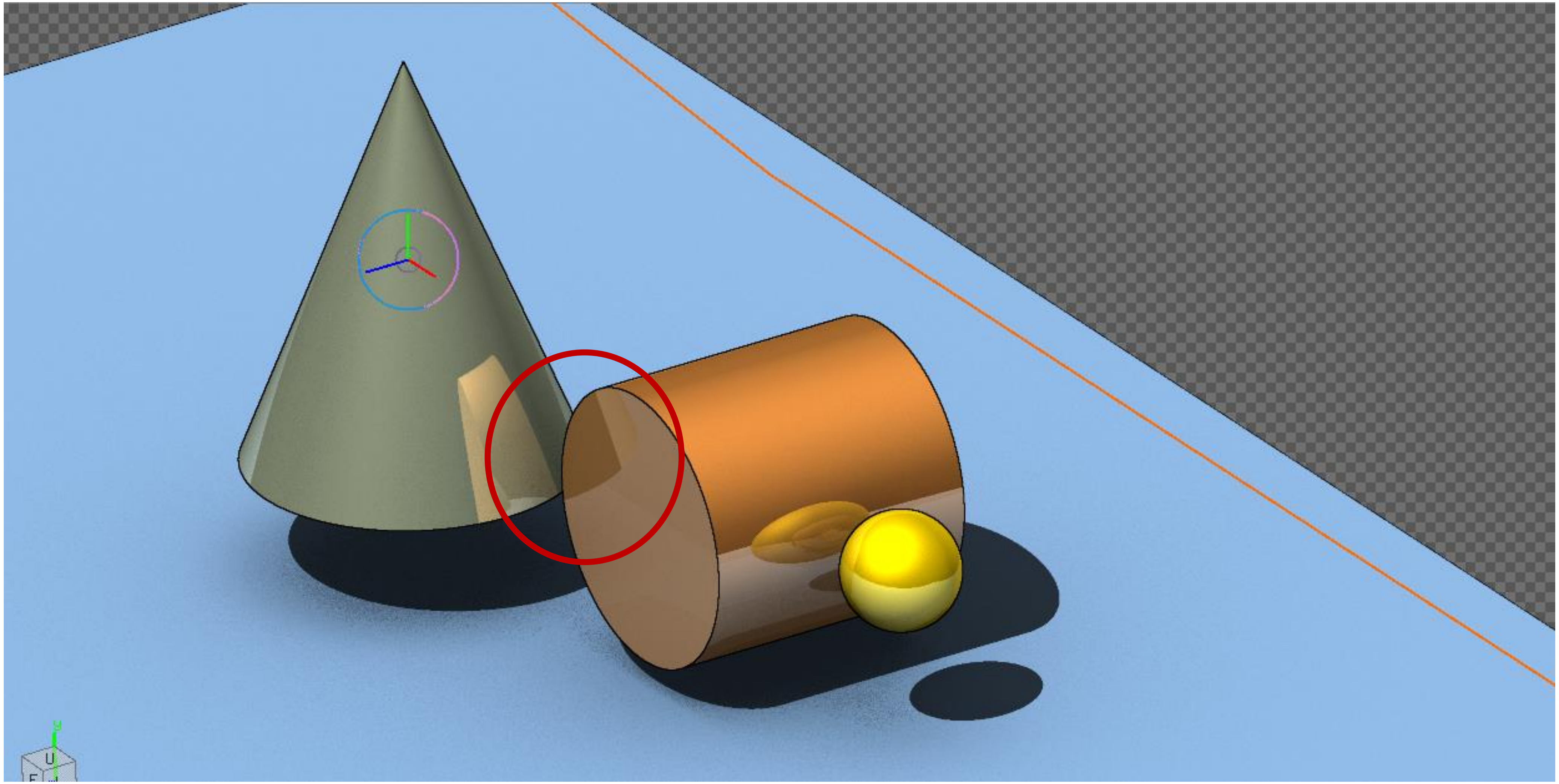


Diffuse reflection model



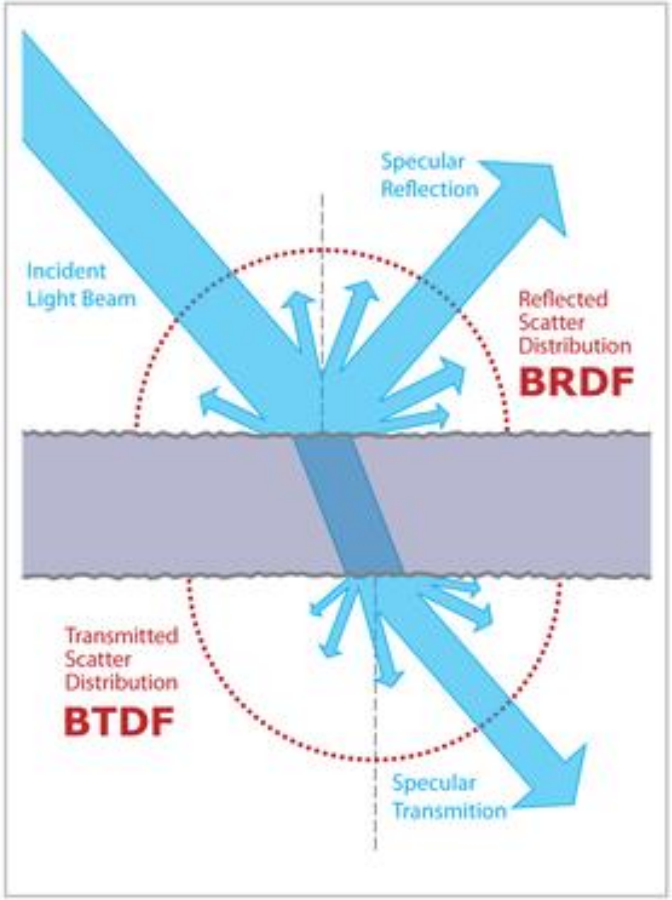
Specular reflection model

Refraction - IOR



Material parameters

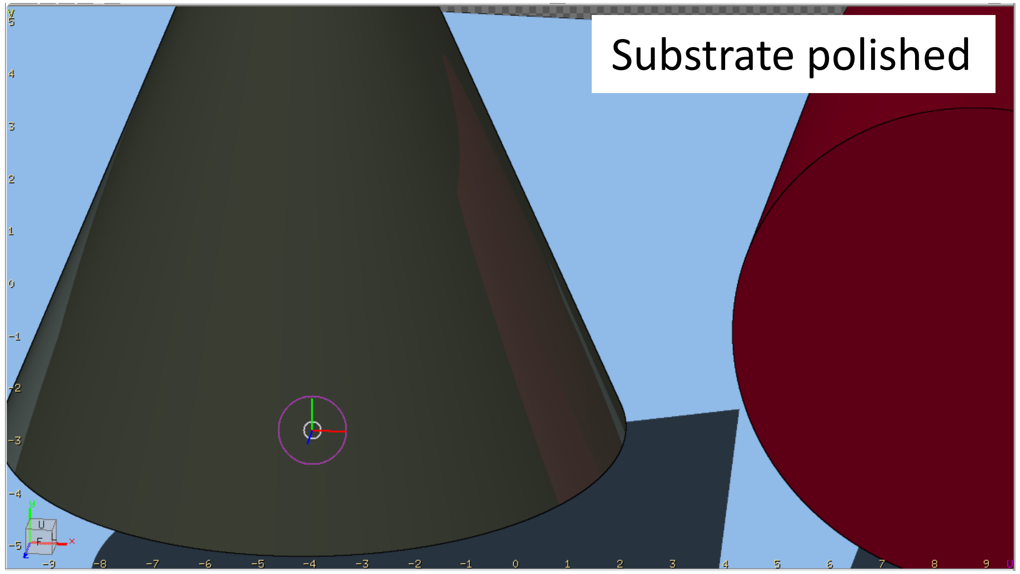
BxDF parameter = interaction model for photons with material. It combines BRDF (bi-directional reflection distribution function), BSDF (bi-directional scattering distribution function) and BTDF (bi-directional transmission distribution function)

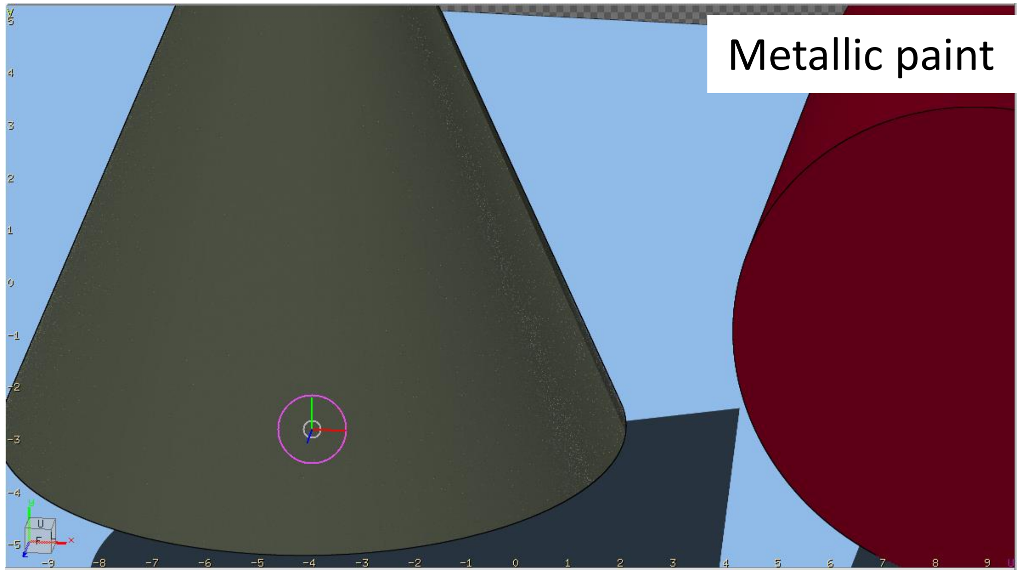


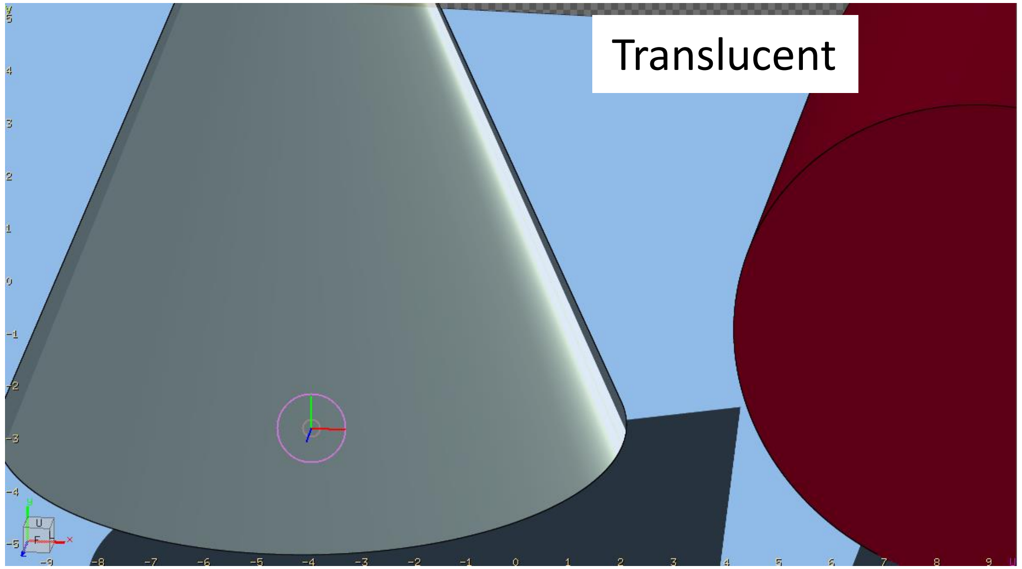
The default is a simple "phong" model with some enhancements accounting for reflection, refraction & optical absorption. But it's a non-physical approximation and thus, very fast.

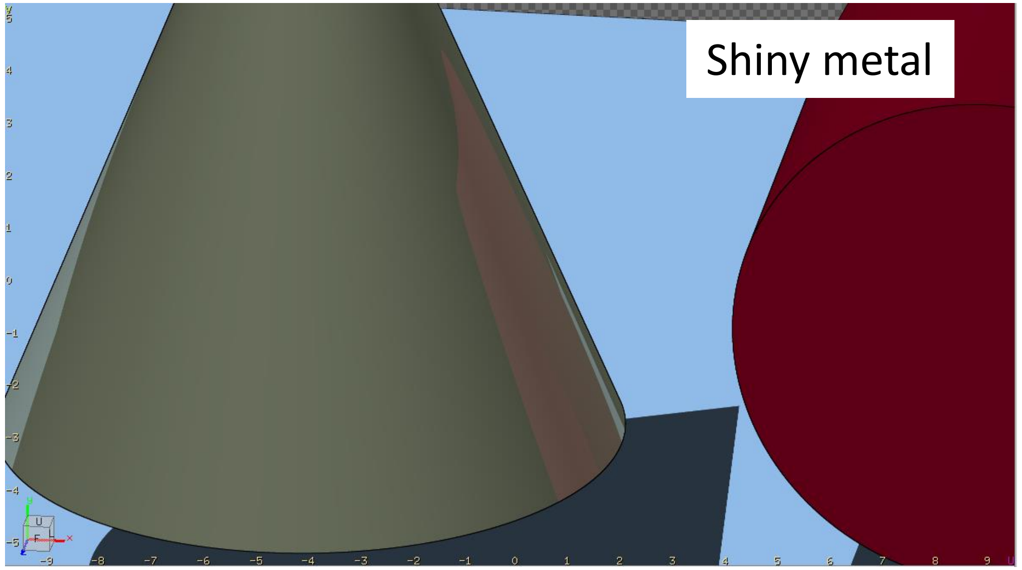
The other BxDFs are based on measured reflectance data or physical interaction models, including micro-facets, anisotropic scattering etc. They are evaluated via Monte Carlo integration and thus, the rendering takes more time!

Material parameters – similar settings different BxDFs

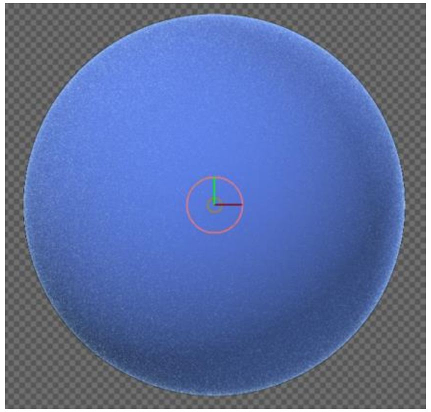


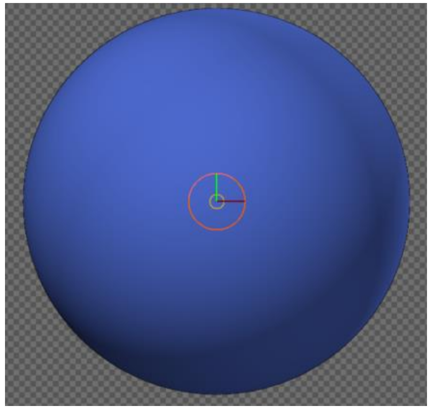


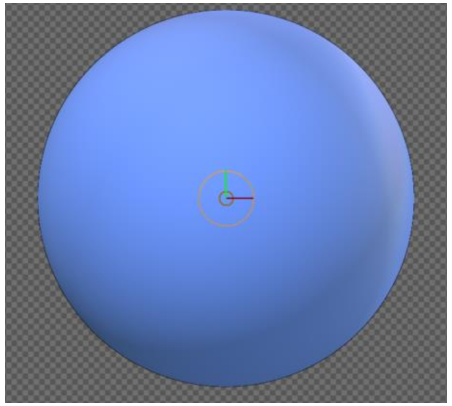


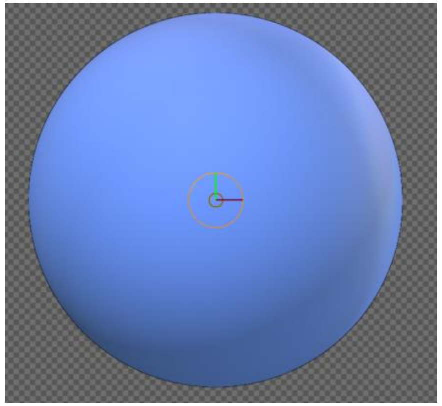


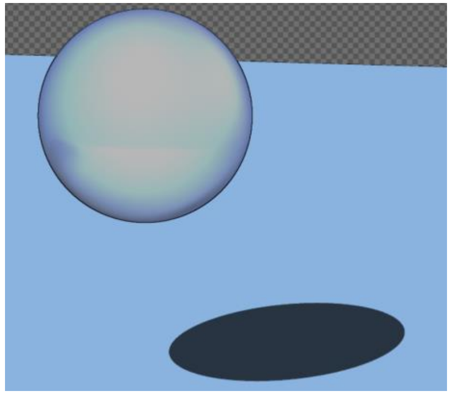
BxDF

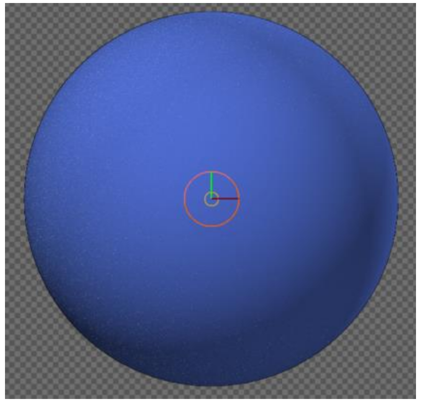

Metallic paint

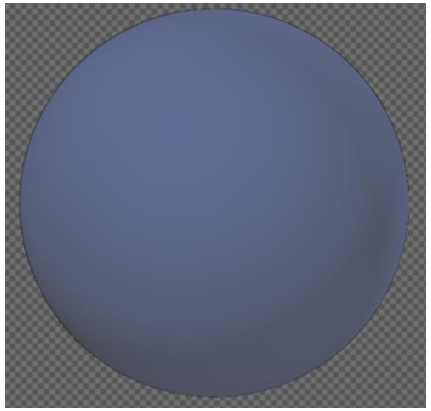

Plastic

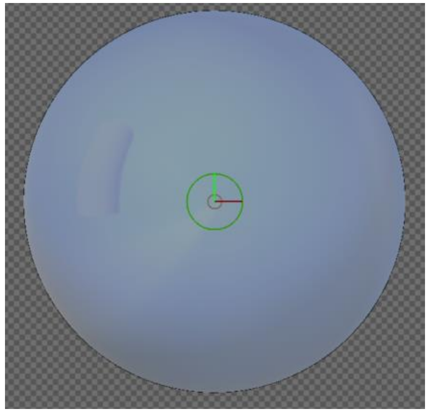

Shiny metal

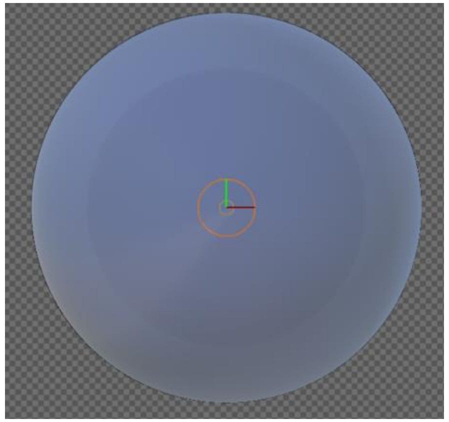

Shiny metal (rough)

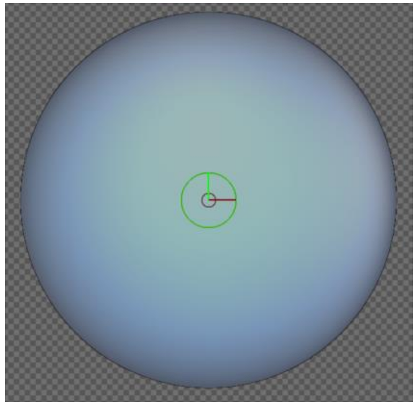

Dispersive glass


Brushed metal


Translucent

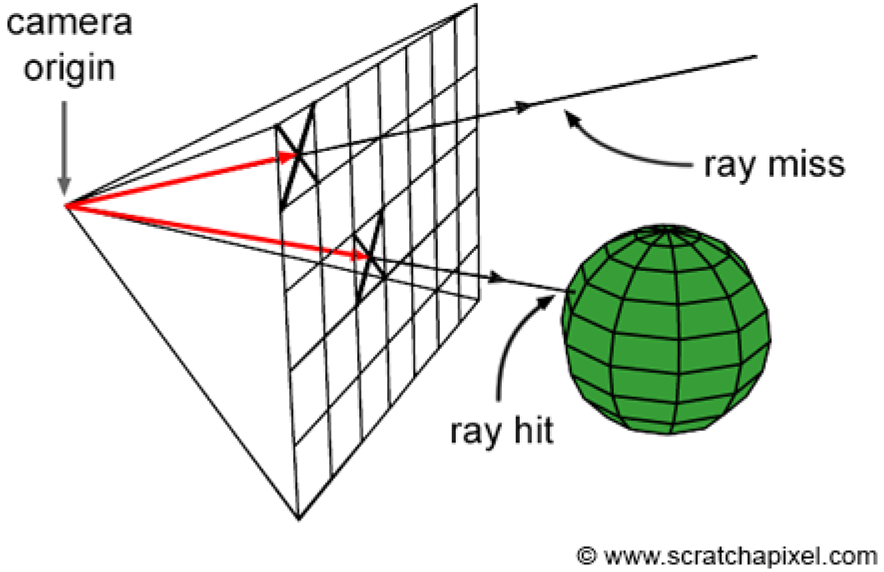

Semi-transparent glass


Clear glass

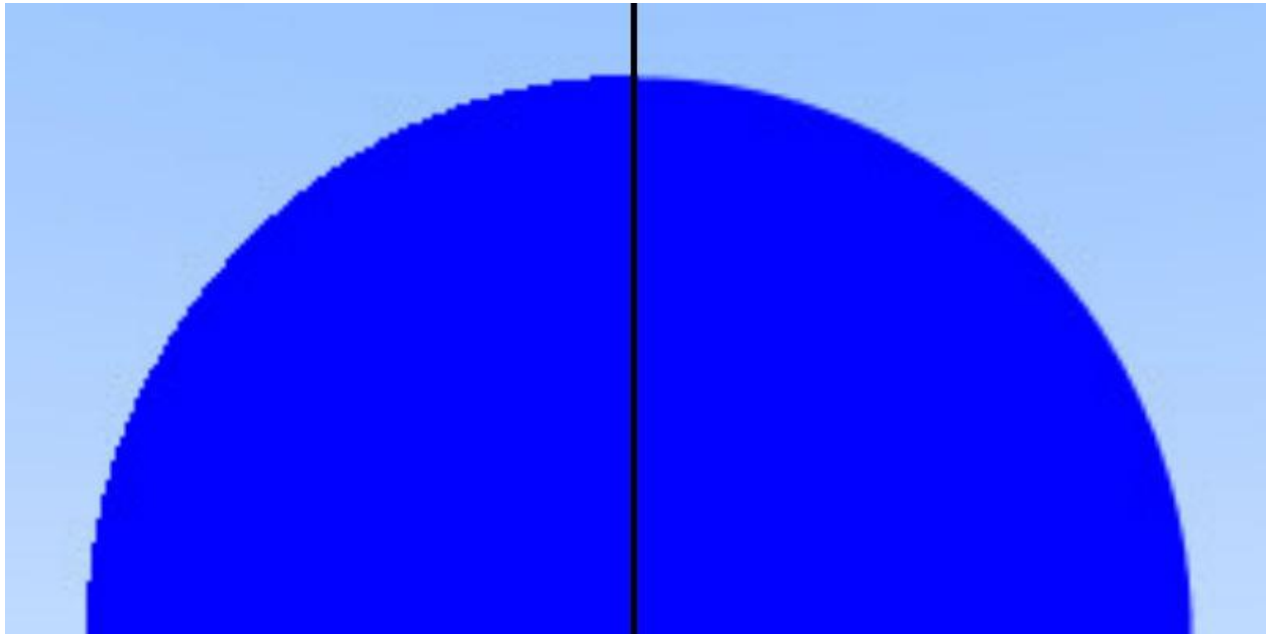

Dispersive glass

Aliasing

Rendering an image is similar to reconstructing a signal. For each pixel a ray is fired and the points that are hit make up the final image.



Due to this “rasterization” that is imposed by the discrete pixel structure the reconstructed image (=signal) might be lacking high frequencies. As a result so called “jaggies” appear which are most notable at edges



Original image

Anti-aliased image

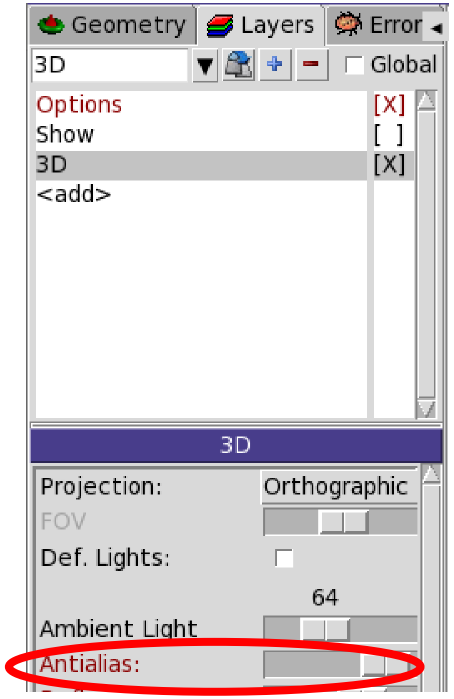
Anti-aliasing

To avoid such artifacts the renderer provides two options:

Standard:

- After the image has been rendered the renderer tries to identify the lack of high frequencies and adaptively re-samples the image in those locations. This is done via a background process and the final image will be displayed once it is ready.

Anti-aliasing:



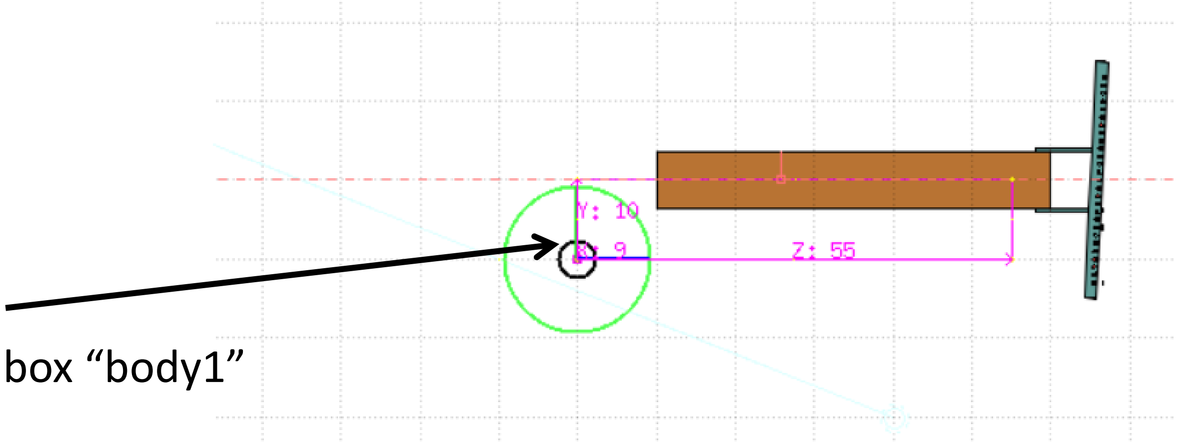
In the options of the 3D layer there is a slider which activates super-sampling of the image. As a consequence all (!) pixels will be sampled at a higher sampling rate and reconstructed via a Mitchell signal filter. This will result in superior image quality but rendering times will double, triple, etc. depending on the number of super-samples that are selected.

Display of mesh data (USRBIN) – via clipping

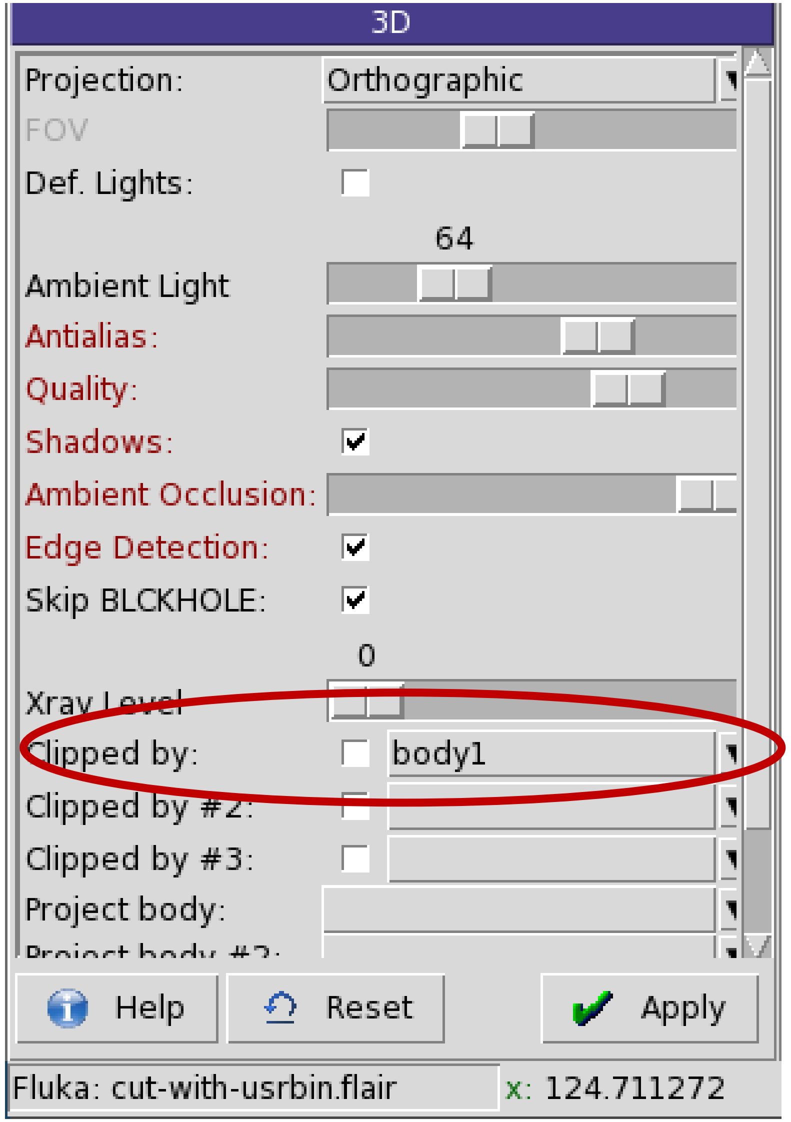
<u>Create a cut-out volume:</u>

1. Create a body (e.g. a box) that is not used in a region
2. Move this body over the part of the geometry from which it should be cut out

3. In the "Layers" – "3D" tab select this body as "clipped by". If you tick the check box next to the body's name the body is not subtracted but the intersection of the body & the geometry will be displayed

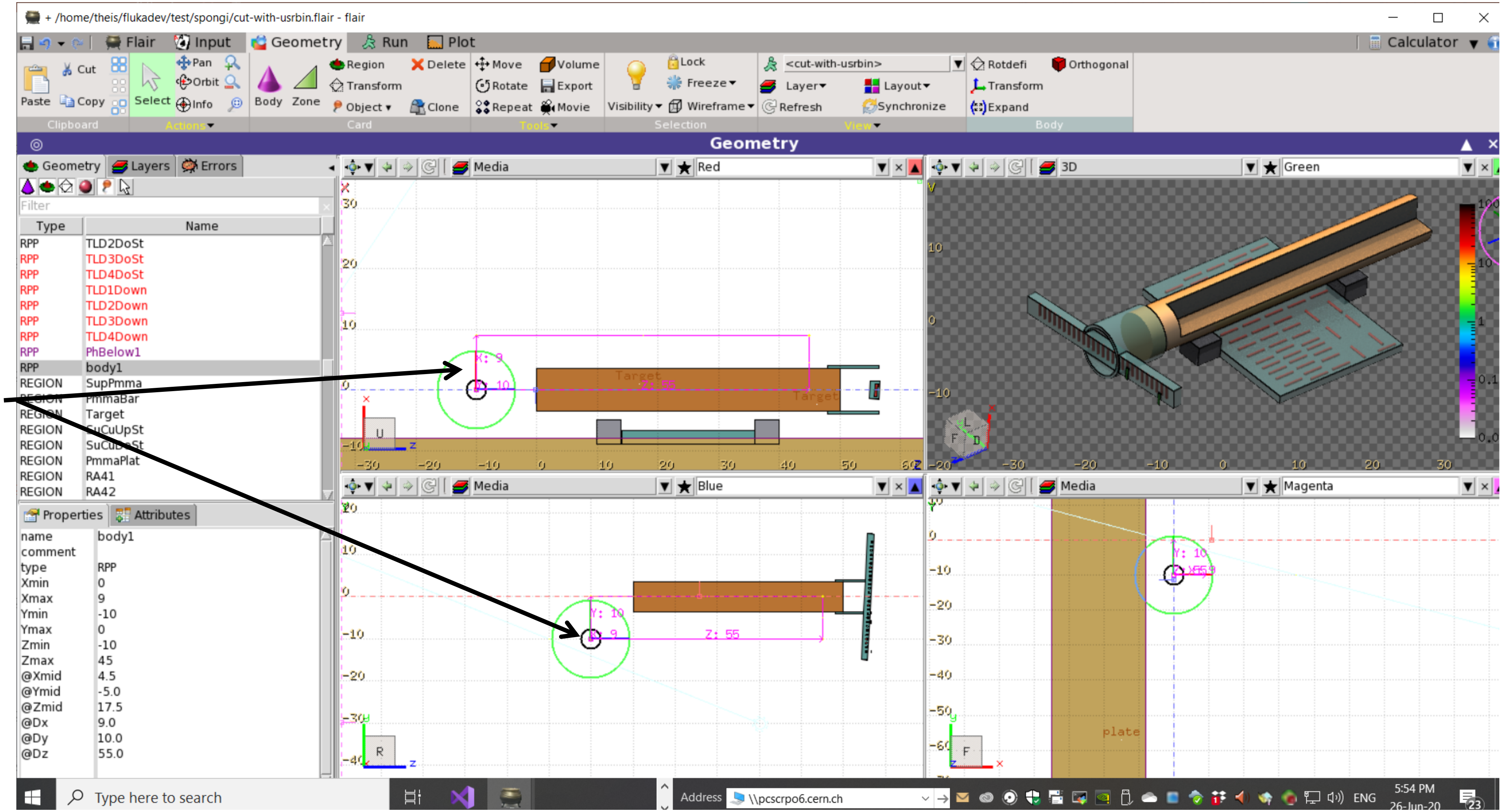


Clipping box "body1"



Display of mesh data (USRBIN) – via clipping

Clipping box "body1"



Display of mesh data (USRBIN) – via clipping

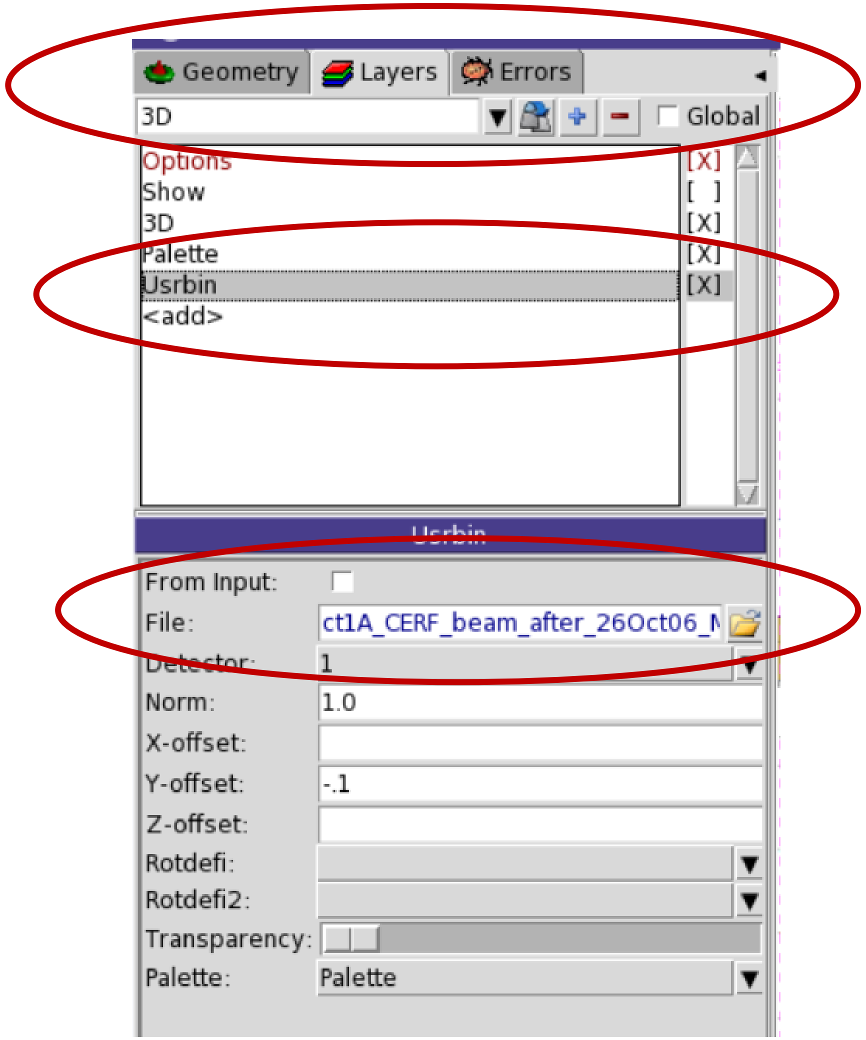
Display mesh data:

1. Open the “layers” tab and select the “3D” layer

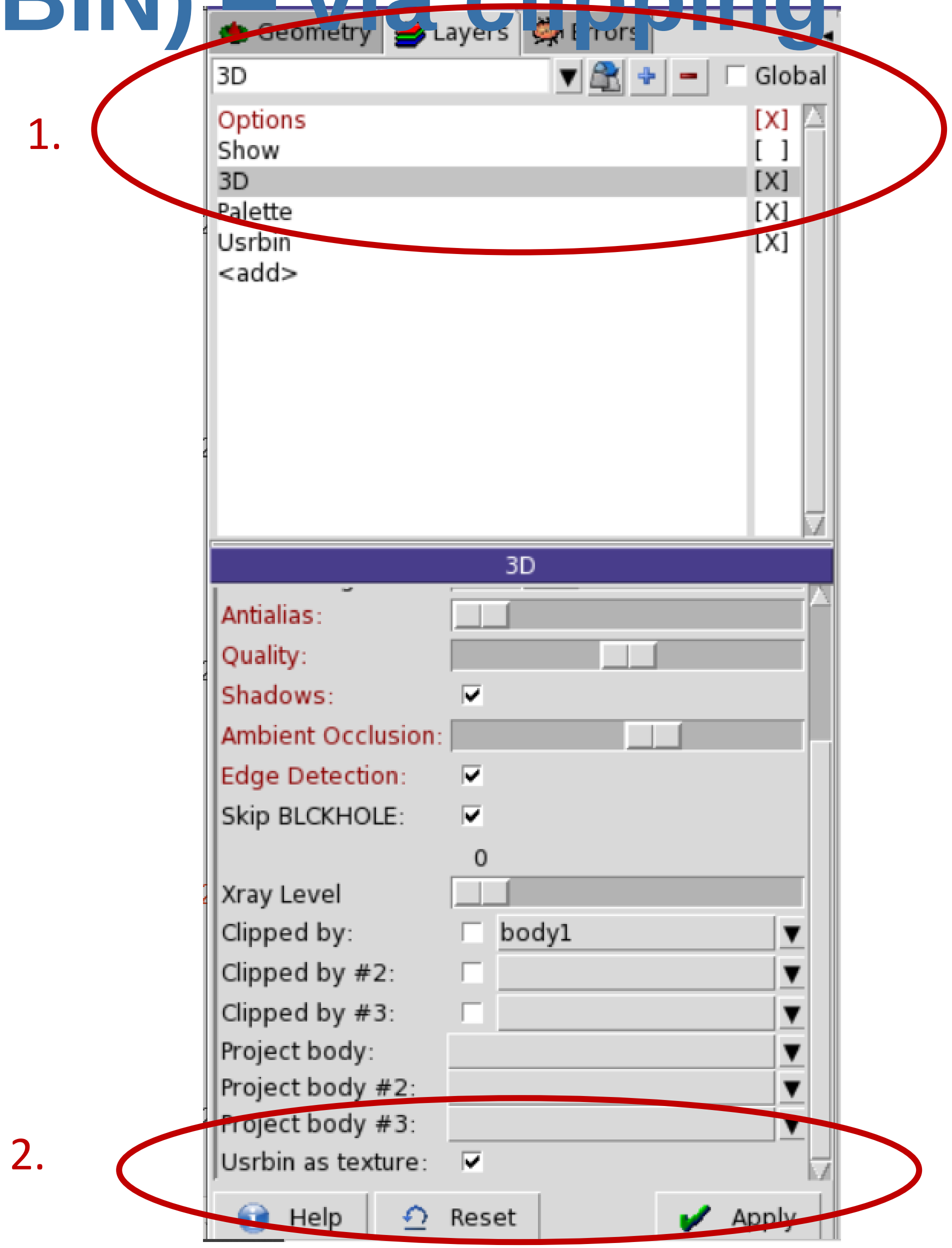
2. Press the “+” button and add a “USRBIN” layer

3. Select the “Usrbin” layer and choose the data source either from the input or from a file in the options at the bottom of the tab

1.
2.
3.



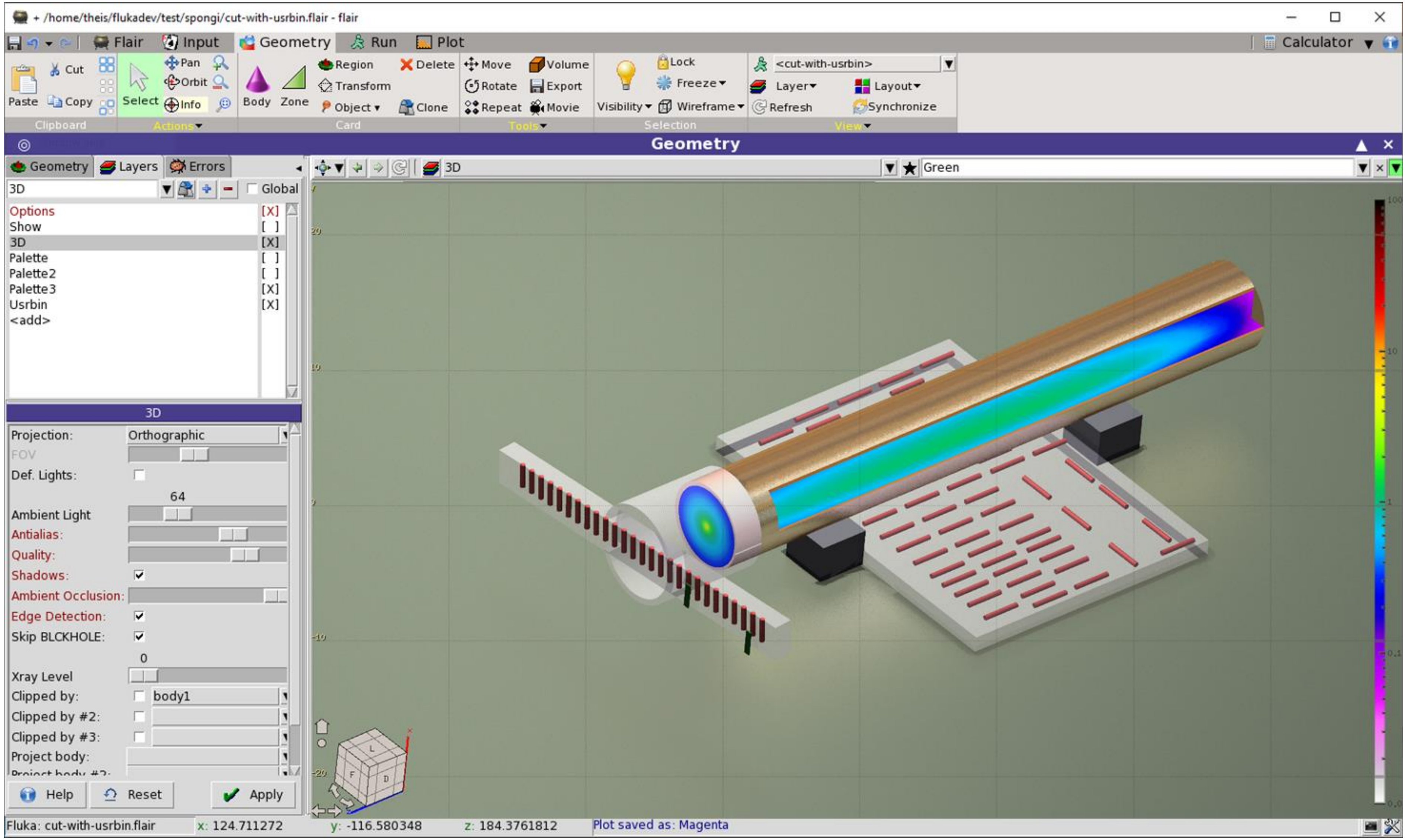
Display of mesh data (USRBIN) – via clipping



<u>Display mesh data:</u>

1. Open the “layers” tab and select the “3D” layer
2. In the options at the bottom tick the “**Usrbin as texture**” option to display the data in the geometry

Display of mesh data (USRBIN) – via clipping

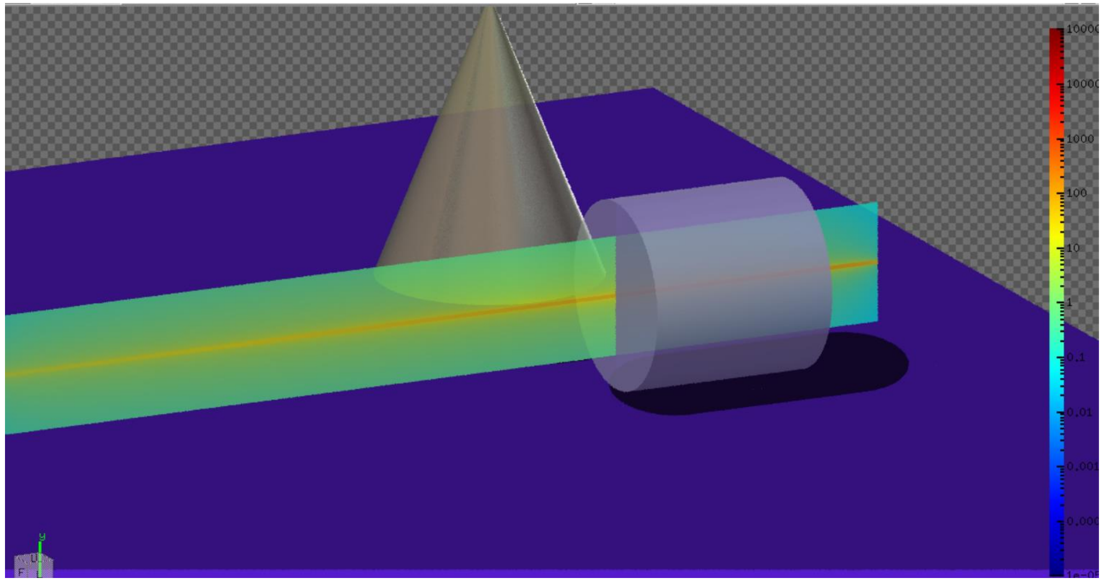


Display of mesh data (USRBIN) – via projection

Concept:

Create a "projection" of mesh data onto a geometric primitive (e.g. plane) which intersects the mesh. At each intersection point the data value will be displayed. The other part of the geometric primitive will be transparent.

NOTE: Setting material/regions to transparent will allow for looking into or through the objects and show the mesh data within an object.



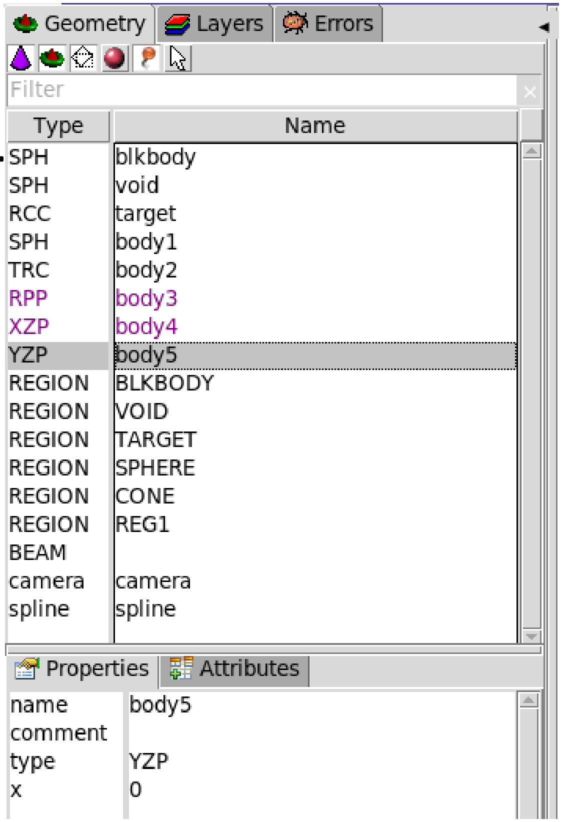
Requires: Flair >= 3.2

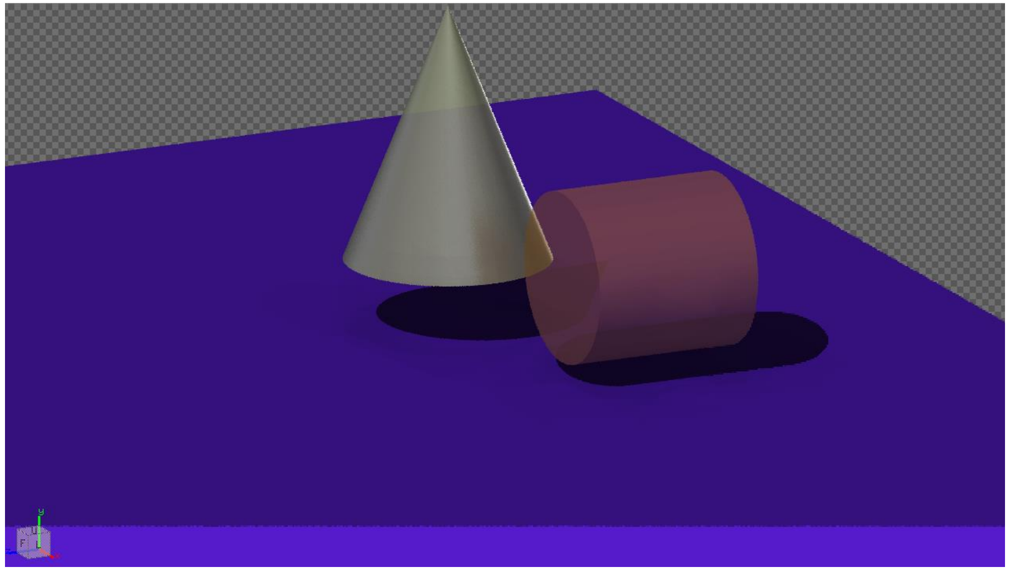
Display of mesh data (USRBIN) – via projection

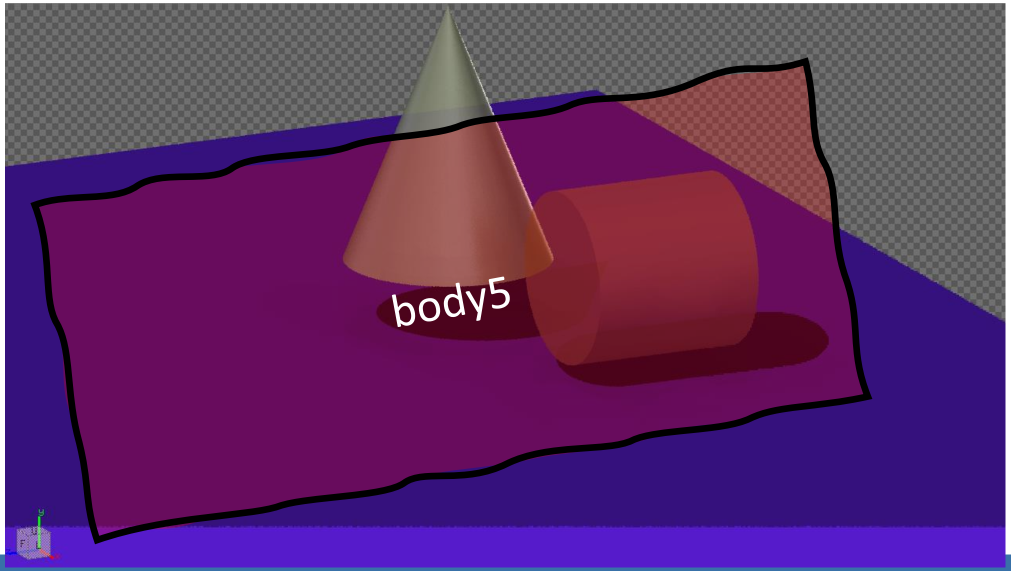
Display the mesh data:

1.) Create a geometric primitive (e.g. plane)

2.) Move it to the position where it will intersect a data mesh and where you want to visualize the data values.







Display of mesh data (USRBIN) – via projection

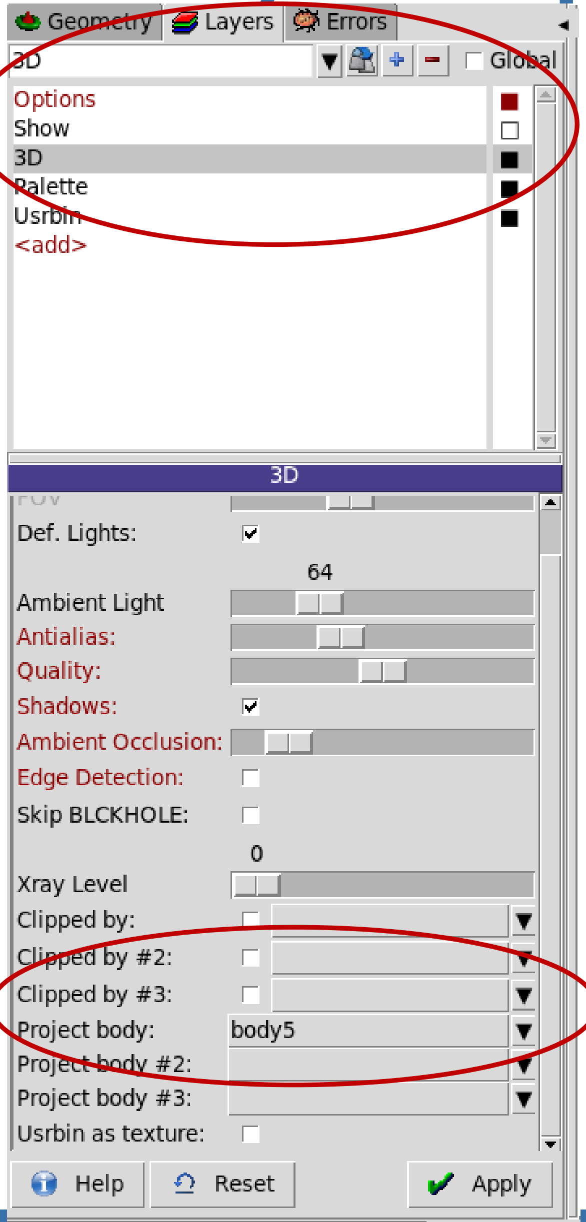
Display the mesh data:

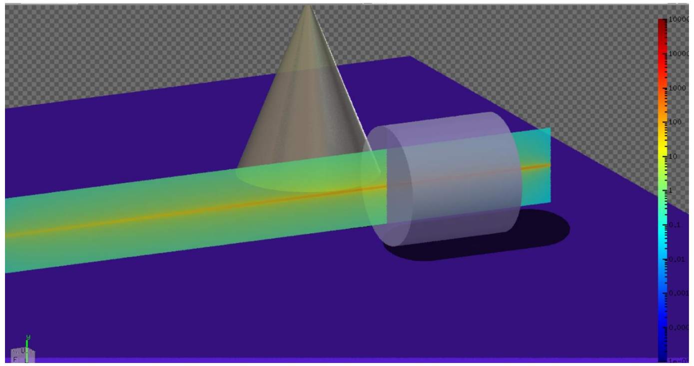
3.) Go to the “Layers” tab and select the 3D options

4.) In the “projection body” drop-down box select one or more primitives that you would like to use to visualize the data.

NOTE:

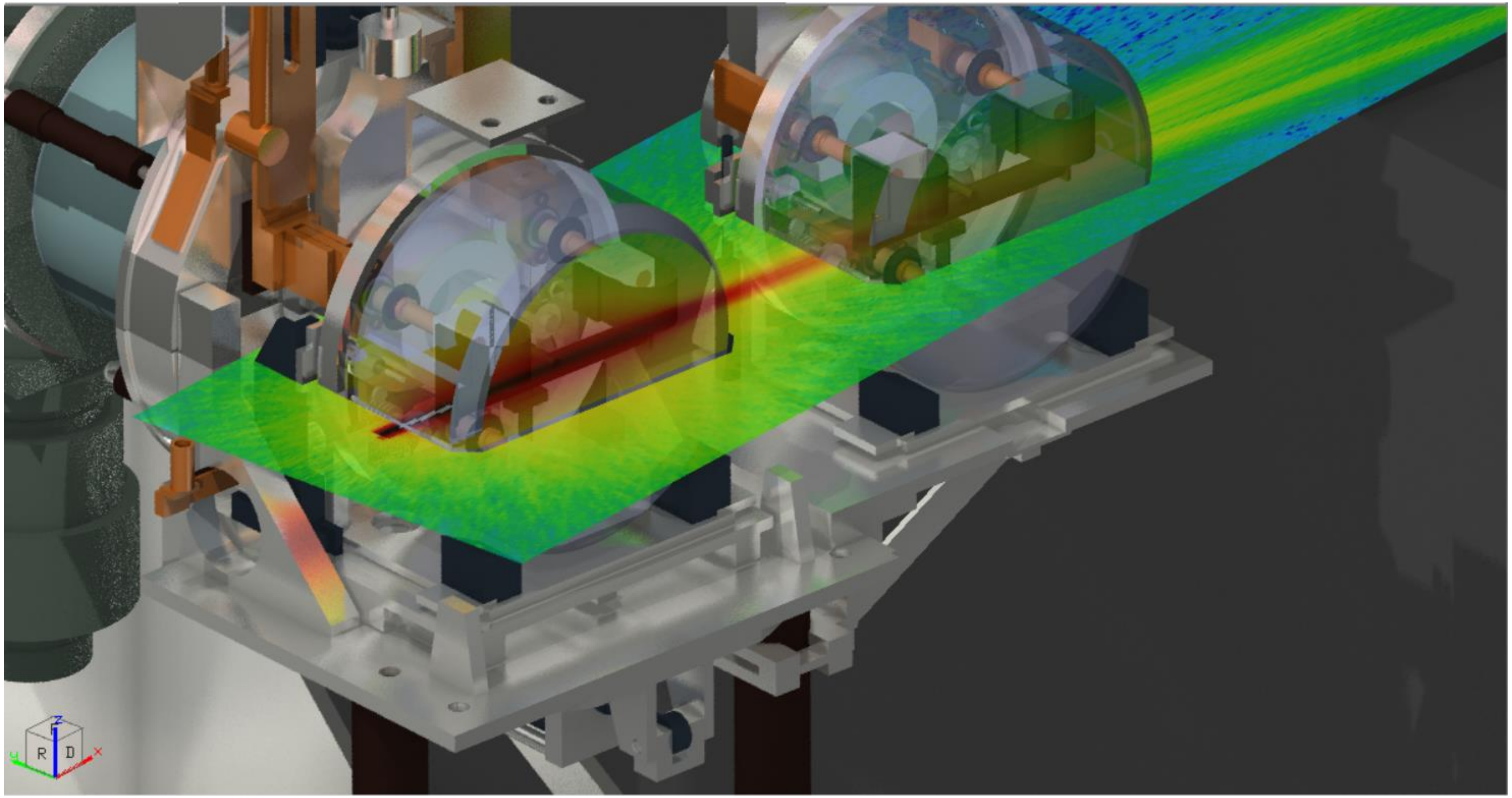
- The primitives do not need to be used elsewhere in the geometry!
- This is best when combined with transparency of material and region.





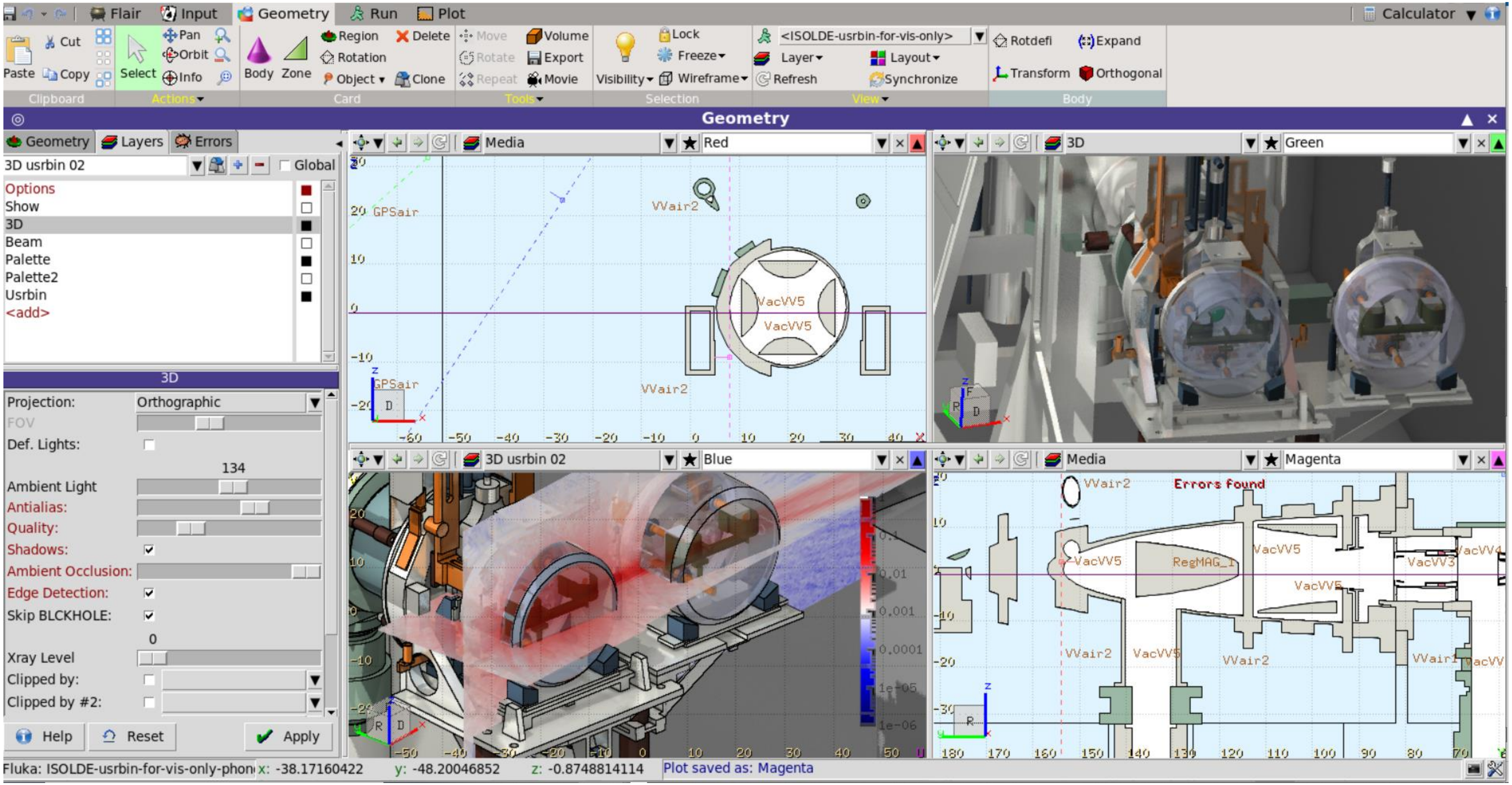
Display of mesh data (USRBIN) – via projection

For example



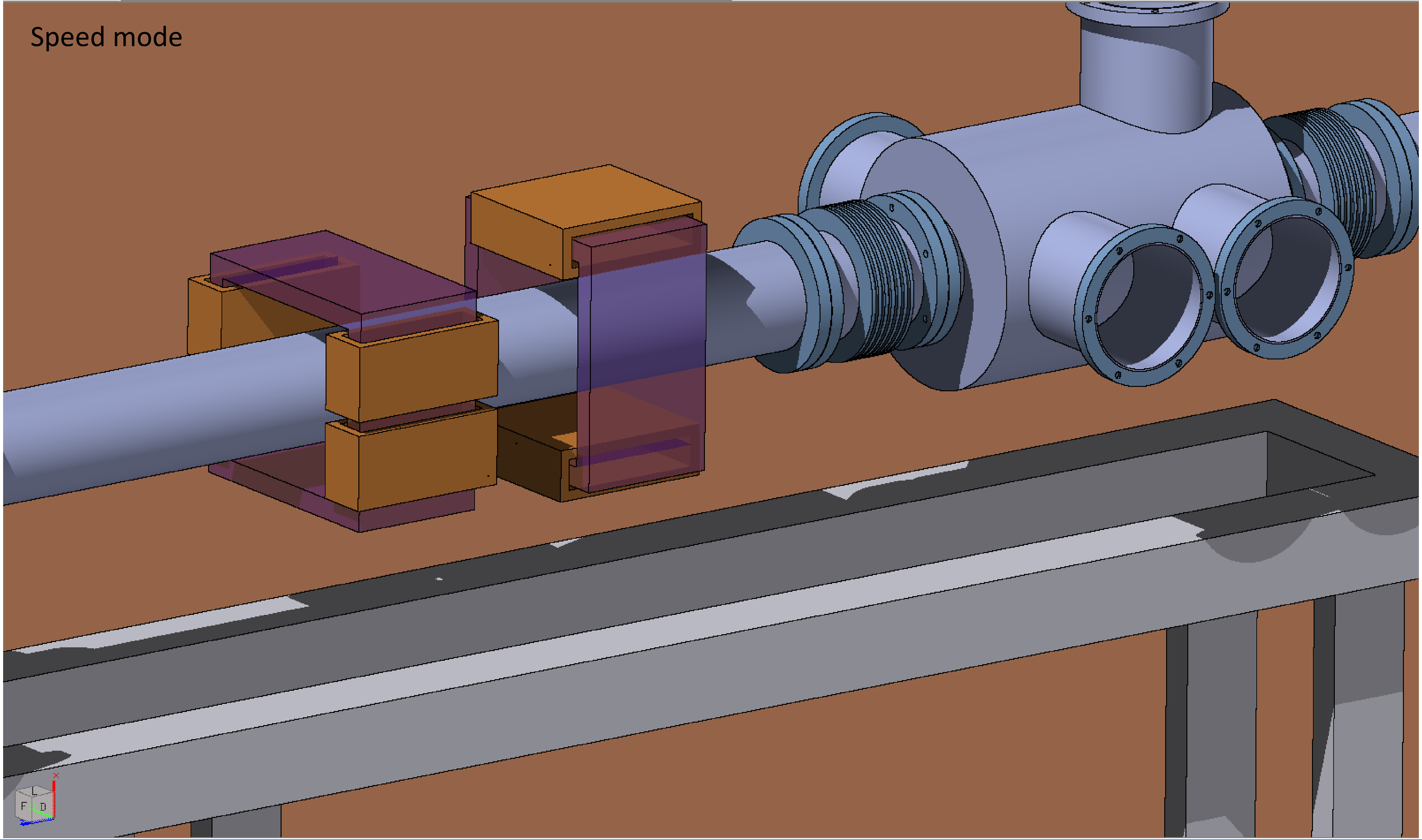
Display of mesh data (USRBIN) – via projection

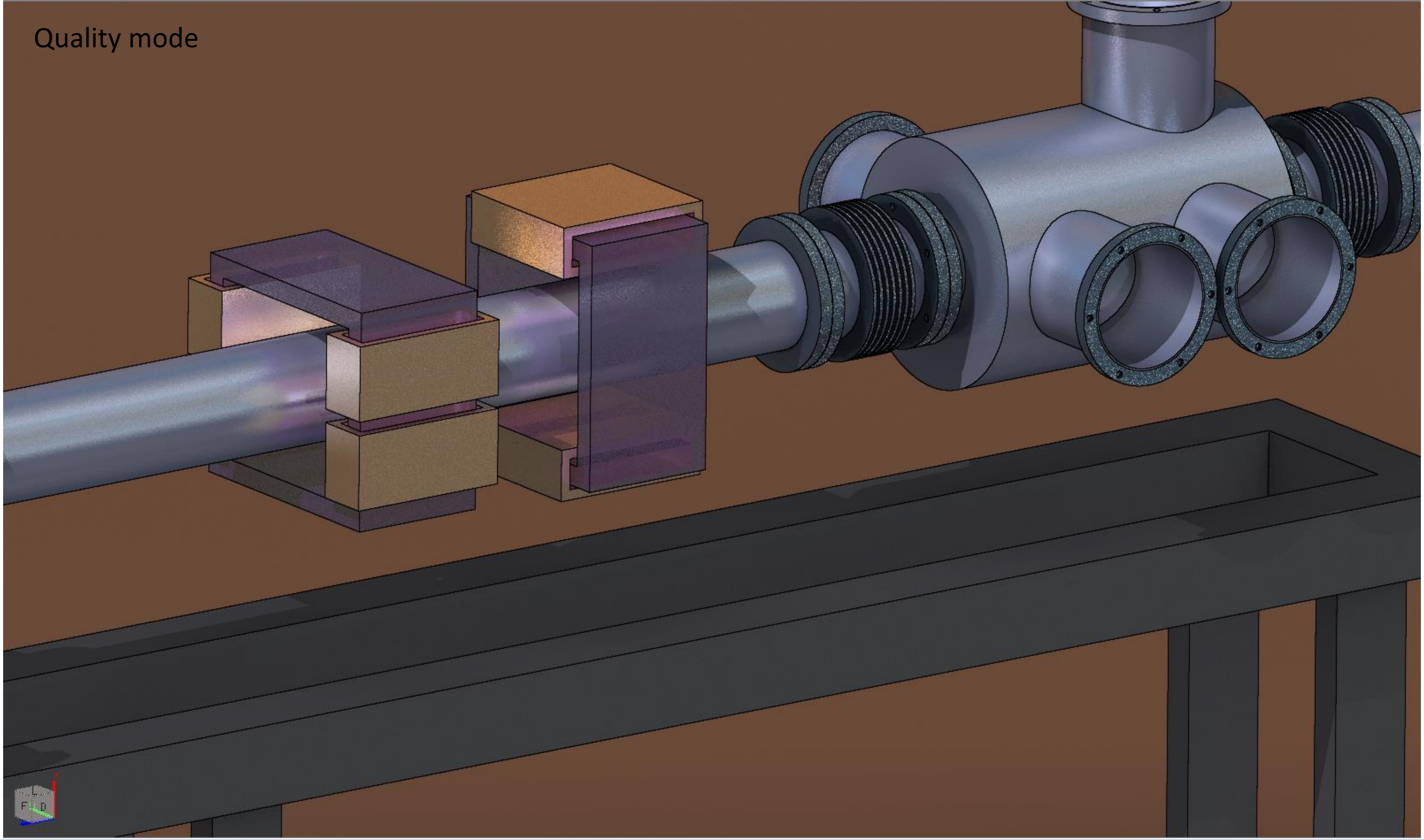
For example

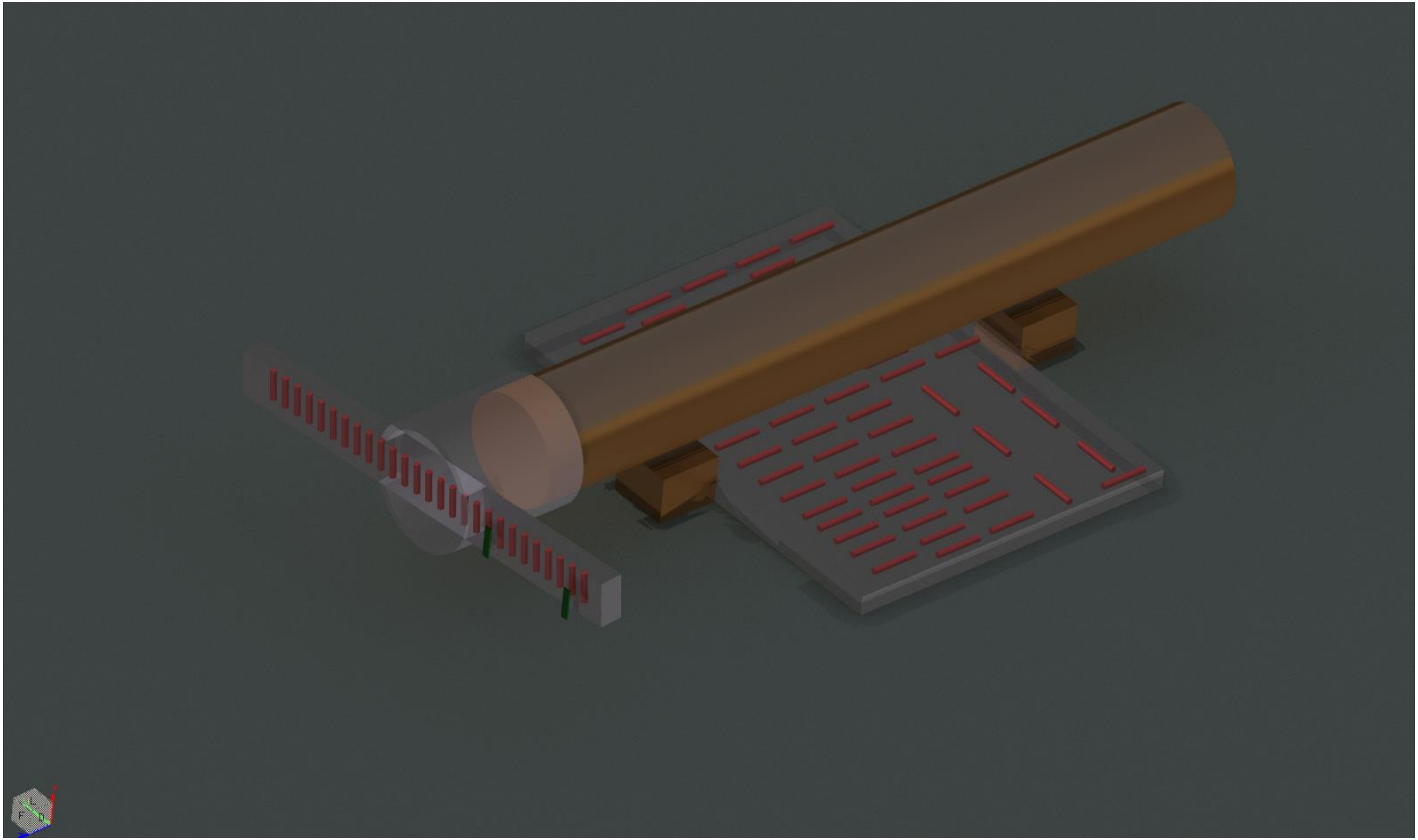


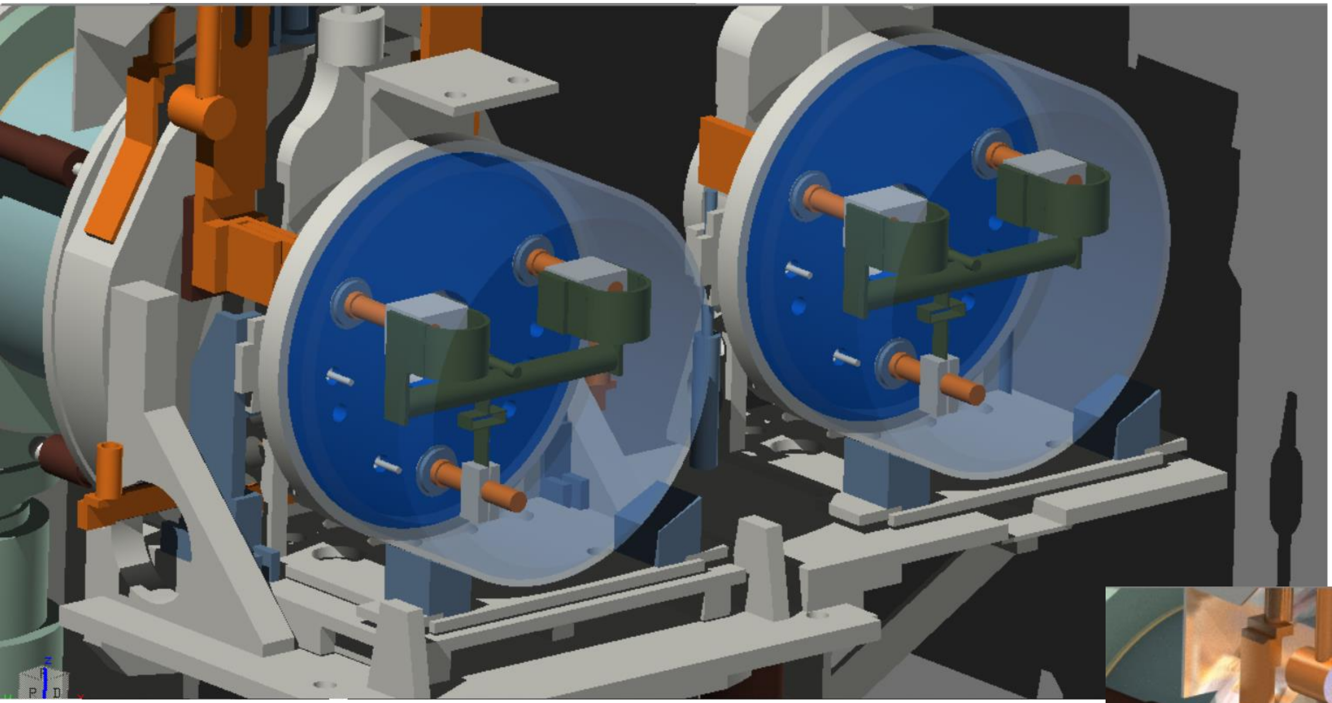
Some more examples

Speed mode



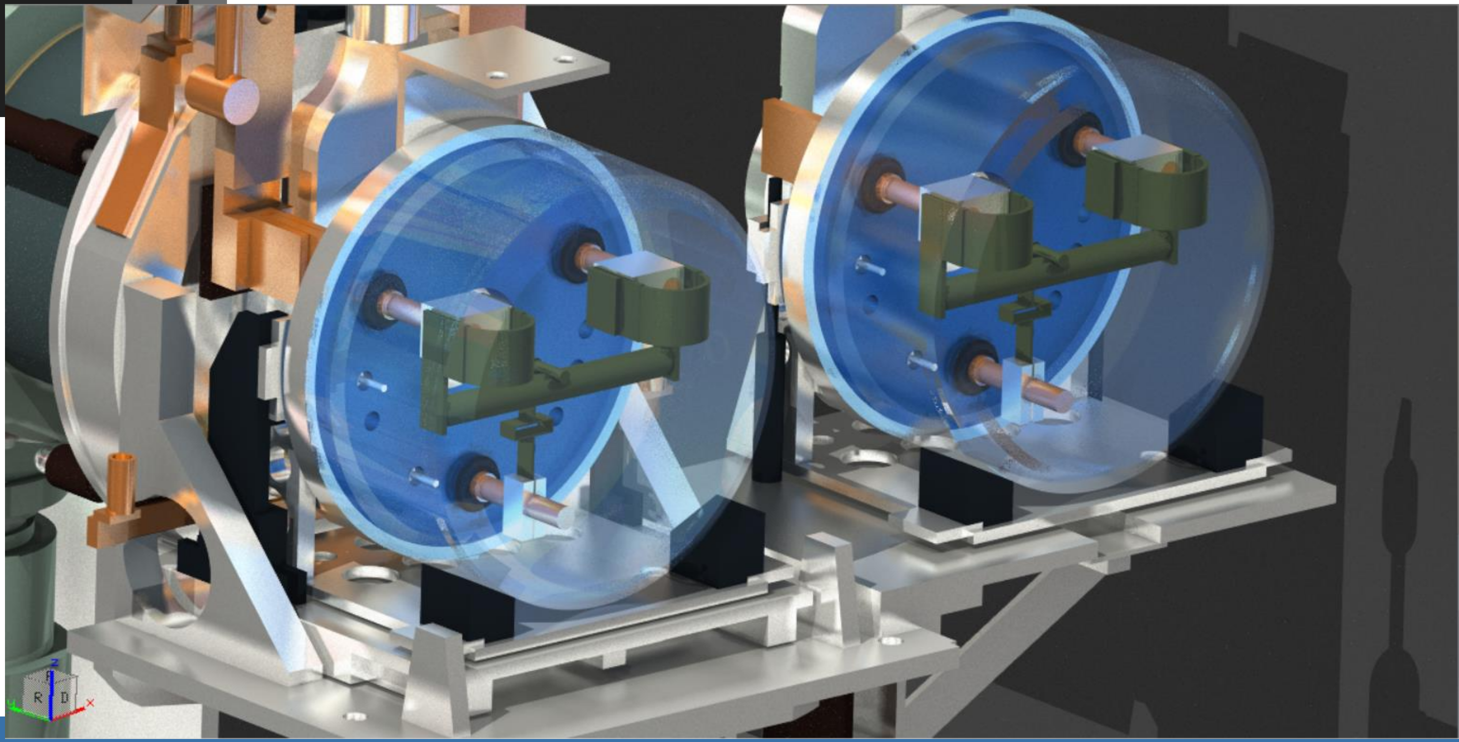

Quality mode

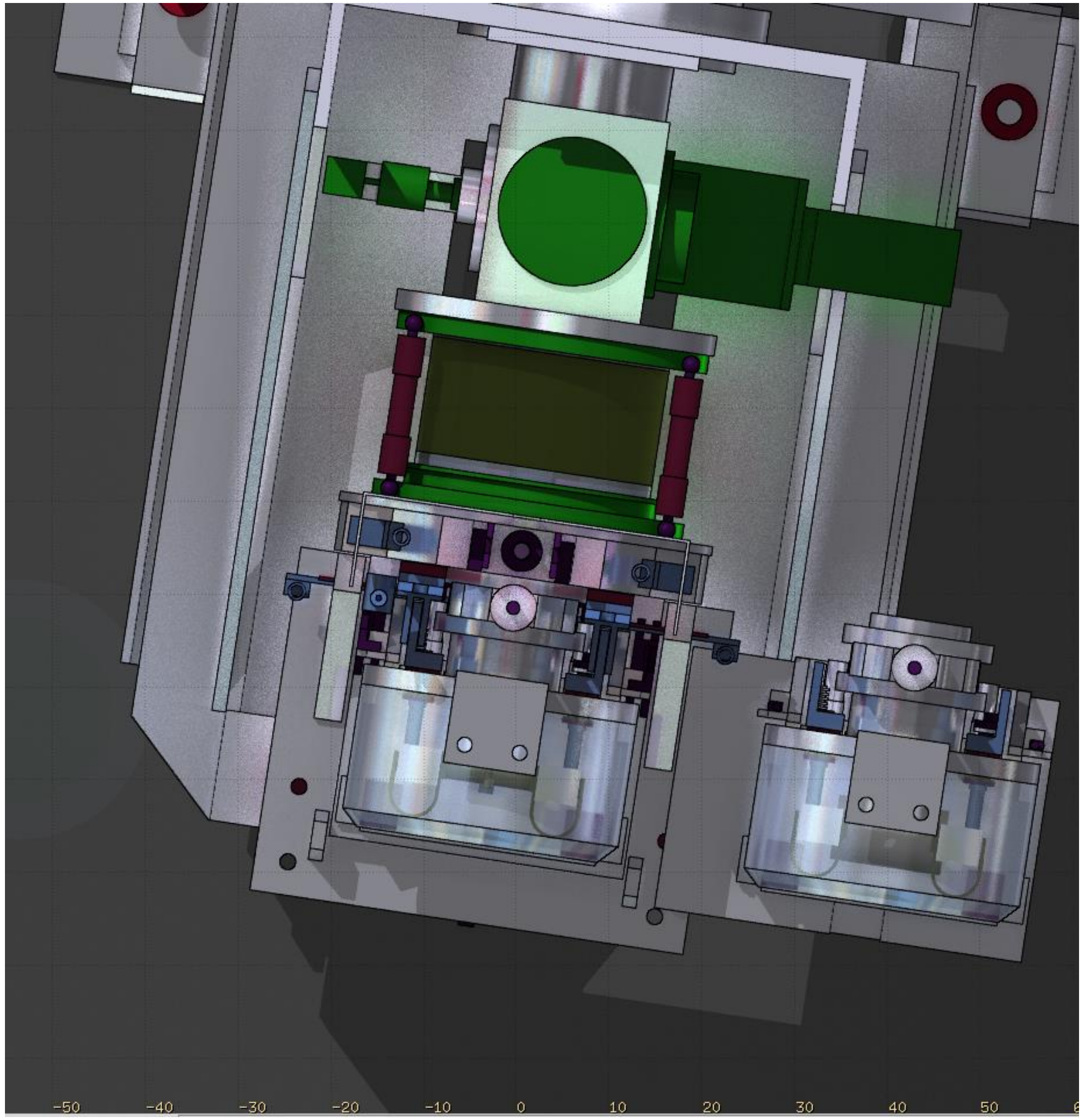




Speed mode

Quality mode

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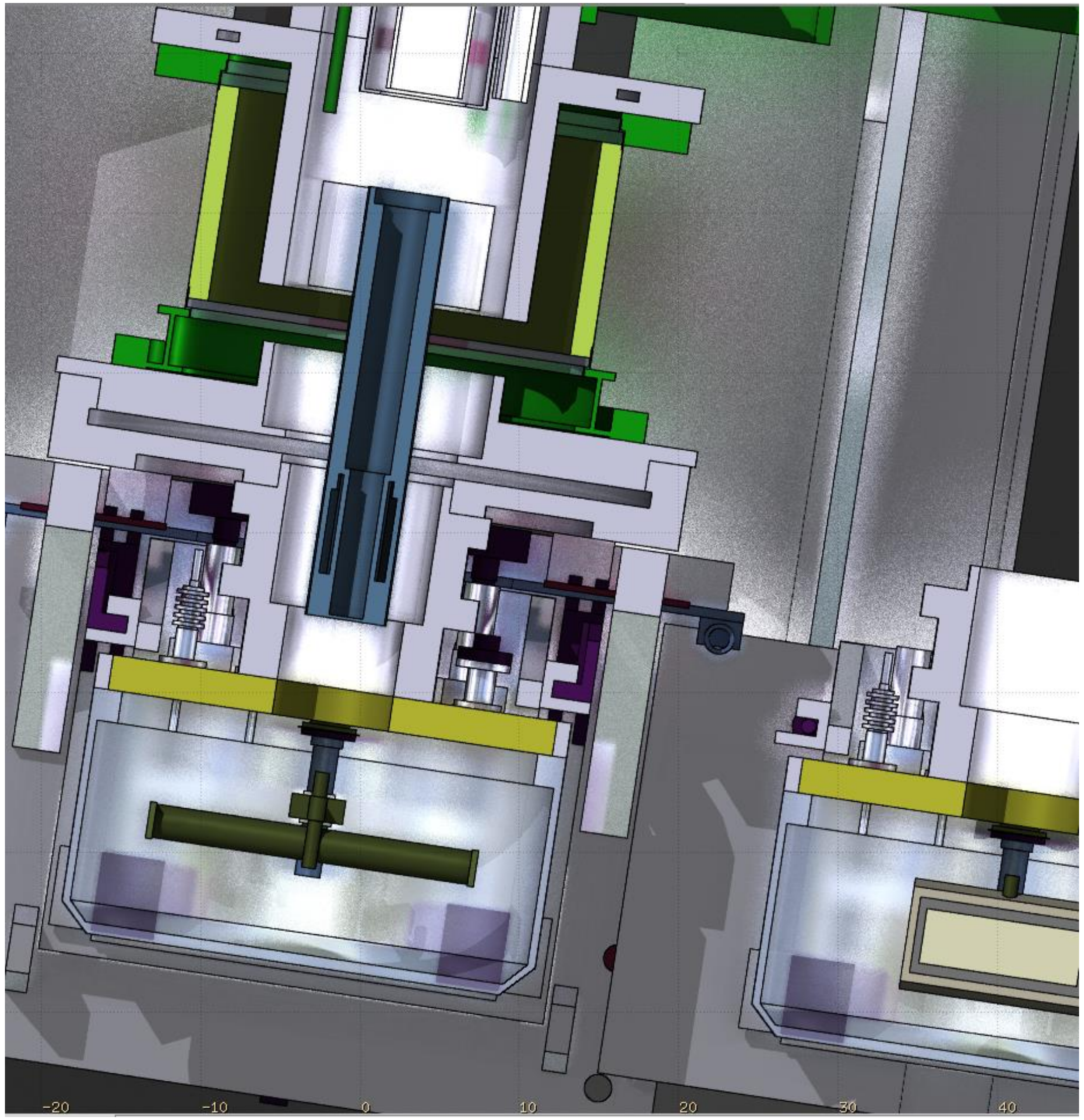
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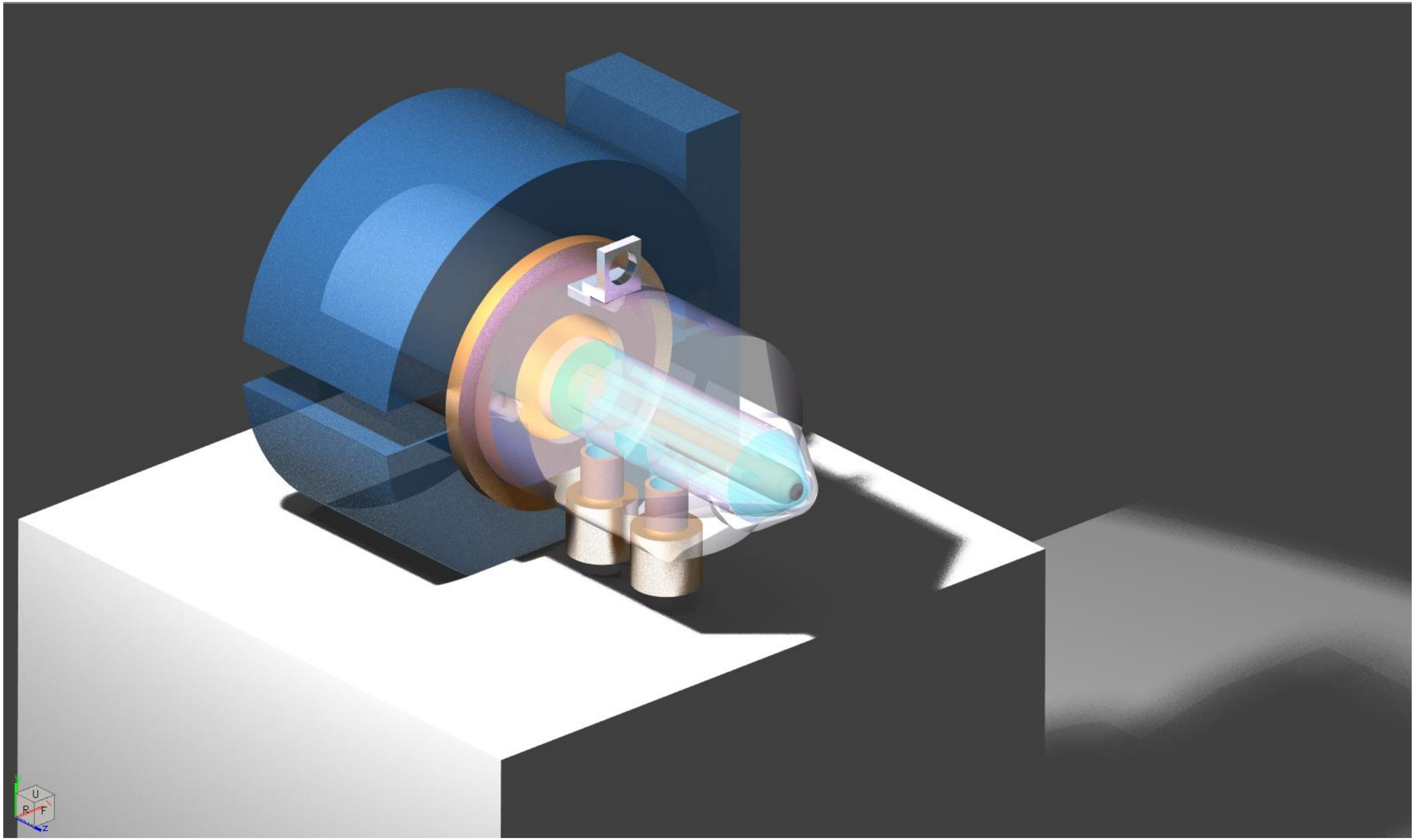

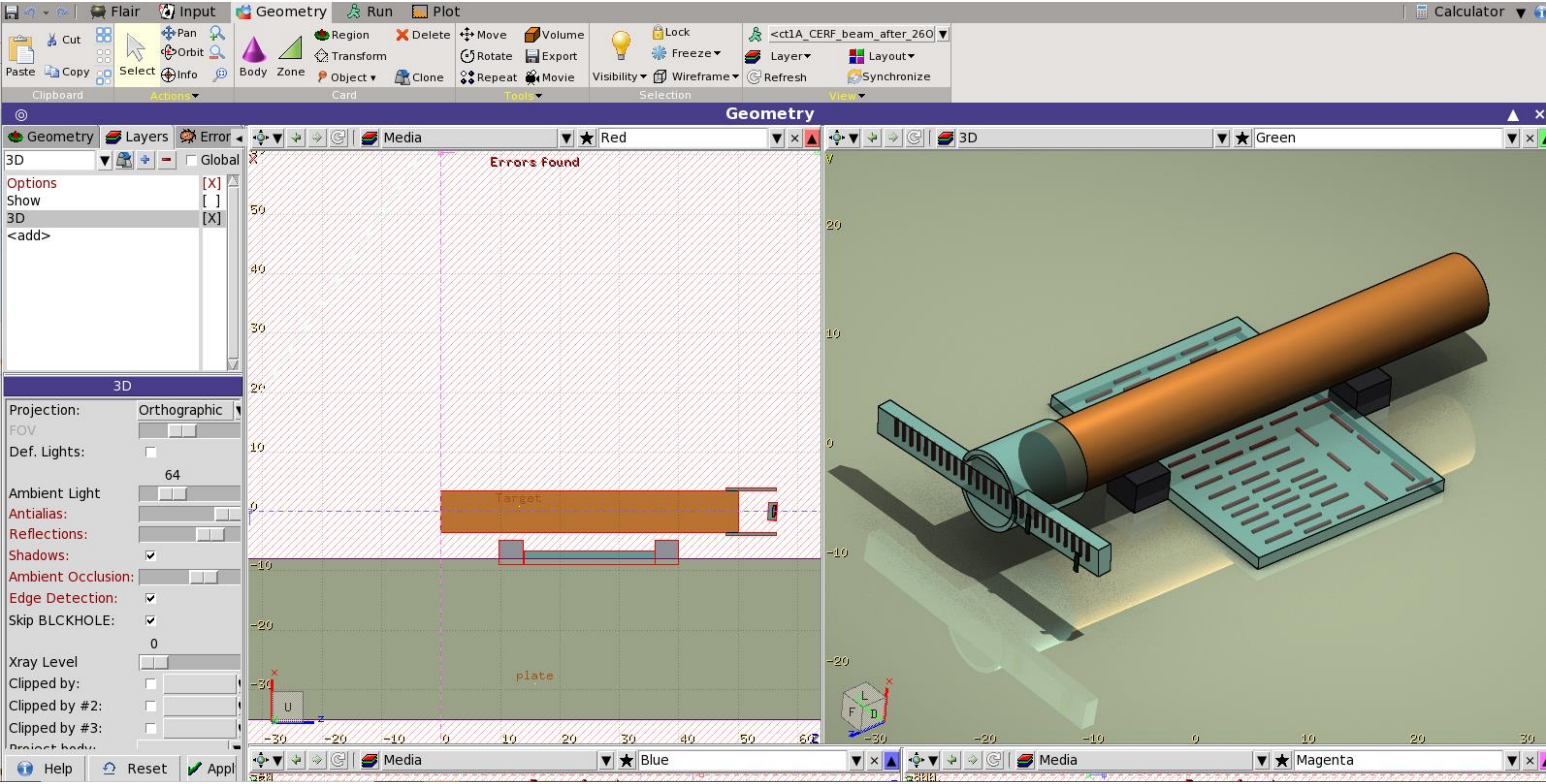
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Geometry
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Calculator
Paste
Cut
Copy
Select
Pan
Orbit
Info
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Zone
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Transform
Object
Delete
Clone
Move
Rotate
Repeat
Volume
Export
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Wireframe
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Layer
Refresh
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Tools
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Global
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Show [ ]
3D [X]
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Projection: Orthographic
FOV
Def. Lights:
64
Ambient Light
Antialias:
Reflections:
Shadows:
Ambient Occlusion:
Edge Detection:
Skip BLCKHOLE:
0
Xray Level
Clipped by:
Clipped by #2:
Clipped by #3:
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Green
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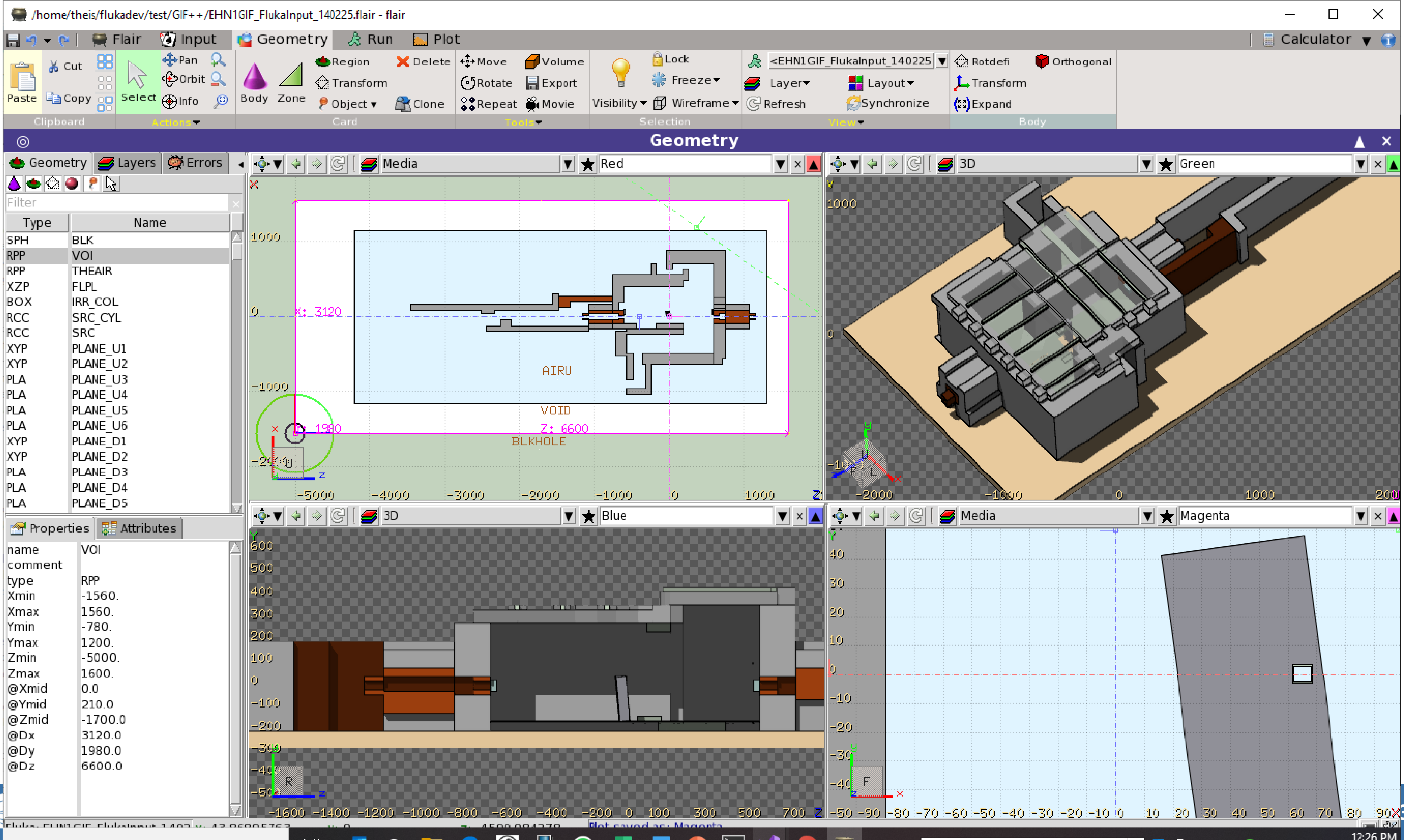
Blue
Media
Magenta


/home/theis/flukadev/test/GIF++/EHN1GIF_FlukaInput_140225.flair - flair
Flair
Input
Geometry
Run
Plot
Calculator
Geometry
Media
Red
3D
Green
Blue
Magenta
Type
Name
SPH BLK
RPP VOI
RPP THEAIR
XZP FLPL
BOX IRR_COL
RCC SRC_CYL
RCC SRC
XYP PLANE_U1
XYP PLANE_U2
PLA PLANE_U3
PLA PLANE_U4
PLA PLANE_U5
PLA PLANE_U6
XYP PLANE_D1
XYP PLANE_D2
PLA PLANE_D3
PLA PLANE_D4
PLA PLANE_D5
Properties
Attributes
name VOI
type RPP
Xmin -1560.
Xmax 1560.
Ymin -780.
Ymax 1200.
Zmin -5000.
Zmax 1600.
@Xmid 0.0
@Ymid 210.0
@Zmid -1700.0
@Dx 3120.0
@Dy 1980.0
@Dz 6600.0
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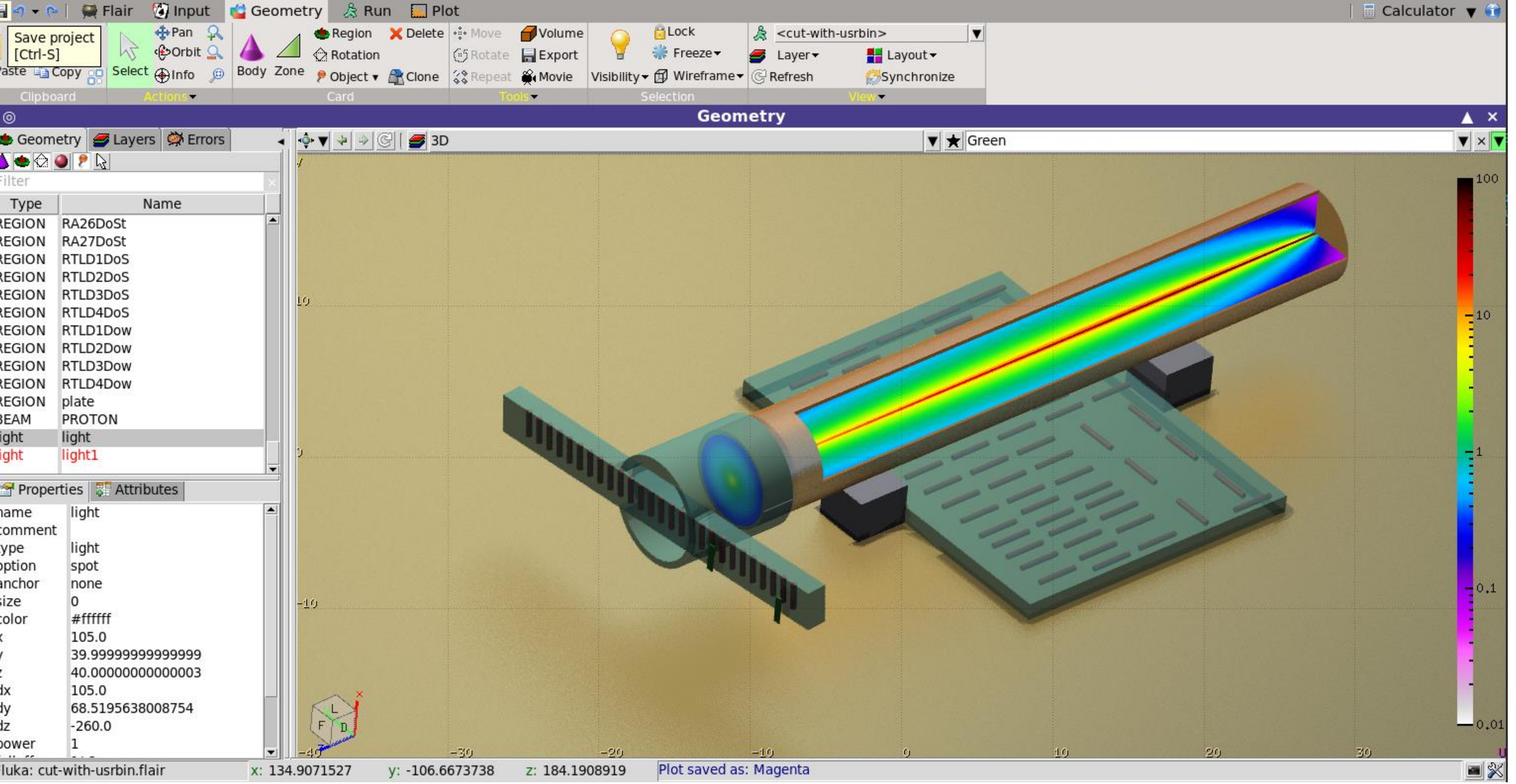
VOID
BLKHOLE
X: 3120
Y: 1980
Z: 6600
Plot saved as: Magenta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Paste
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Wireframe
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Layer
Refresh
Layout
Synchronize
Clipboard
Actions
Card
Tools
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REGION RTLD3DoS
REGION RTLD4DoS
REGION RTLD1Dow
REGION RTLD2Dow
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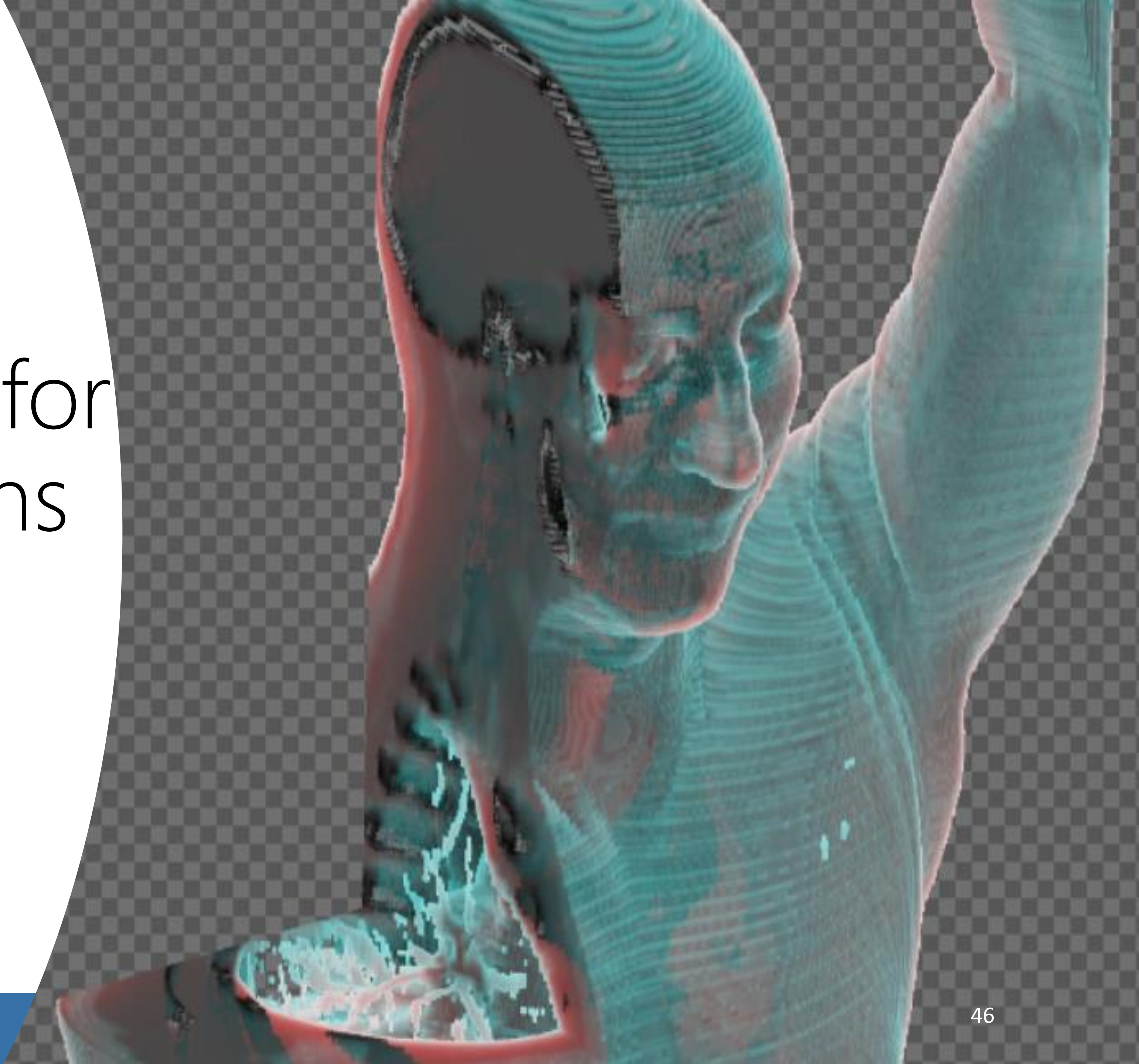
REGION RTLD4Dow
REGION plate
BEAM PROTON
light light
light light1
Properties
Attributes
name light
comment
type light
option spot
anchor none
size 0
color #ffffff
x 105.0
y 39.99999999999999
z 40.00000000000003
dx 105.0
dy 68.5195638008754
dz -260.0
power 1
3D
Green
100
10
1
0.1
0.01
-40
-30
-20
-10
0
10
20
30
fluka: cut-with-usrbin.flair
x: 134.9071527
y: -106.6673738
z: 184.1908919
Plot saved as: Magenta

Geometries courtesy of various members of HSE/RP, EN/STI, EN/EA as well as EP

Volume rendering for medical applications with FARM$_{3D}$



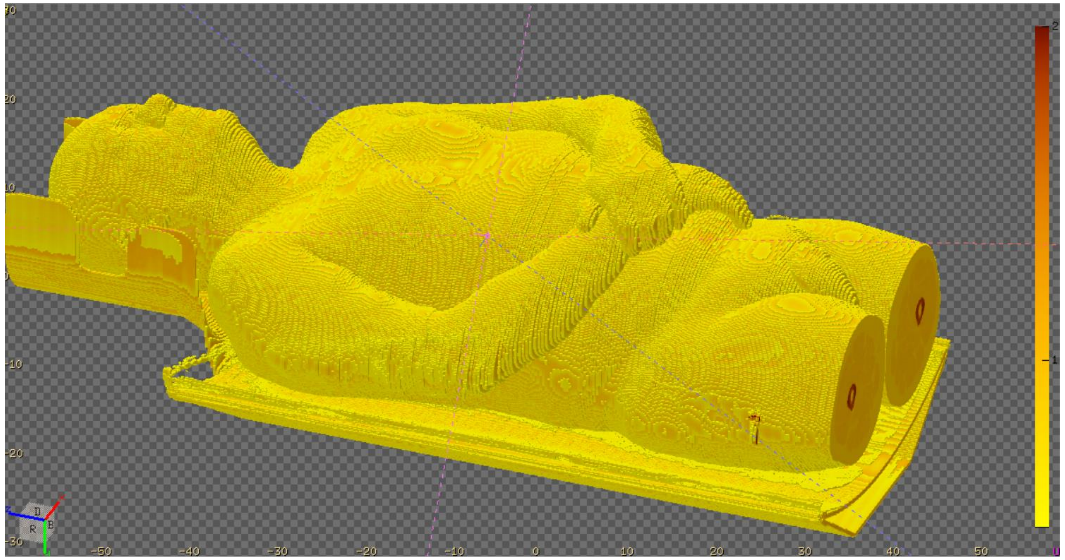
C. Theis, V. Vlachoudis

FLUKA

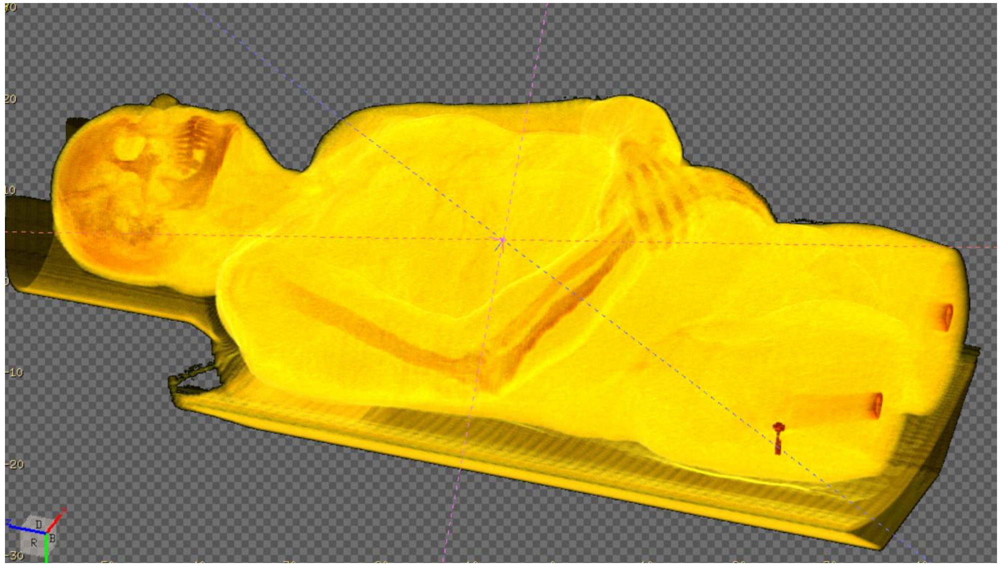
Introduction

Volume rendering is a technique which allows to visualize and understand 3D data acquired typically from MRI or CT scanners. The data are available as a point cloud which

is stored in a 3D voxel structure. Standard surface rendering techniques use a proxy geometry (e.g. cube) to visualize the data, but they fail to reveal 3D relationships like different types of tissue, bones, etc.



Standard surface rendering

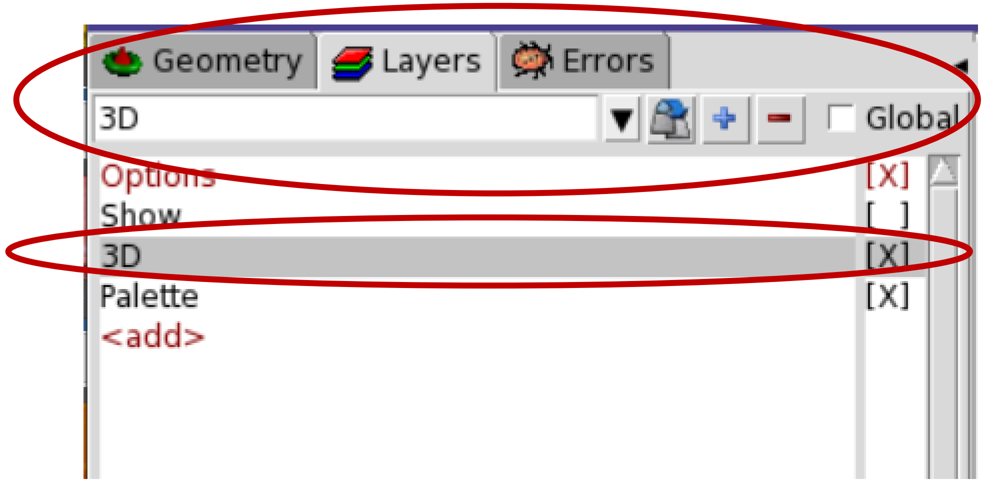


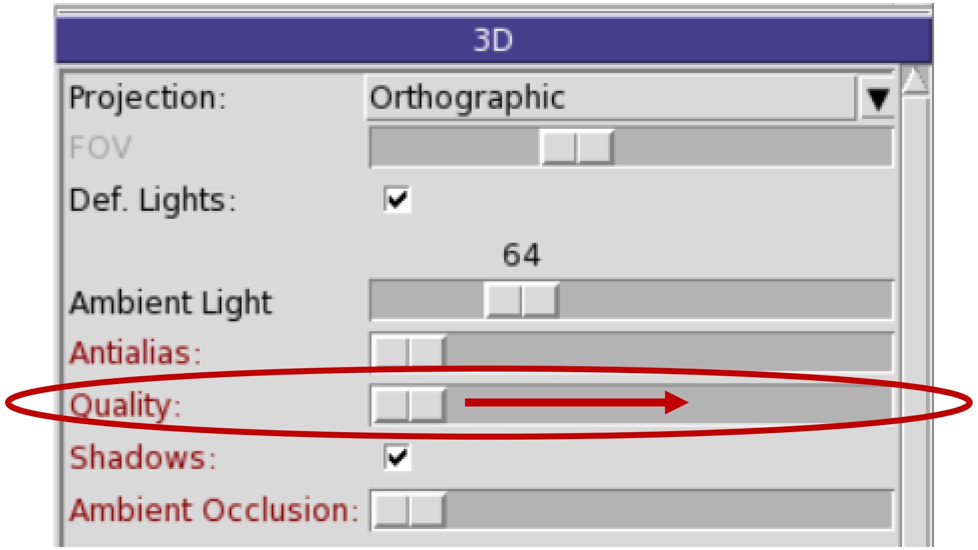
Volume rendering

Activating the volume renderer

The standard renderer in FLAIR is a surface renderer which will also render proxy geometries for voxels. If you want to use the volume renderer you have to activate it by configuring the “3D” layer in the “Layers” tab, moving the “Quality” slider at least one

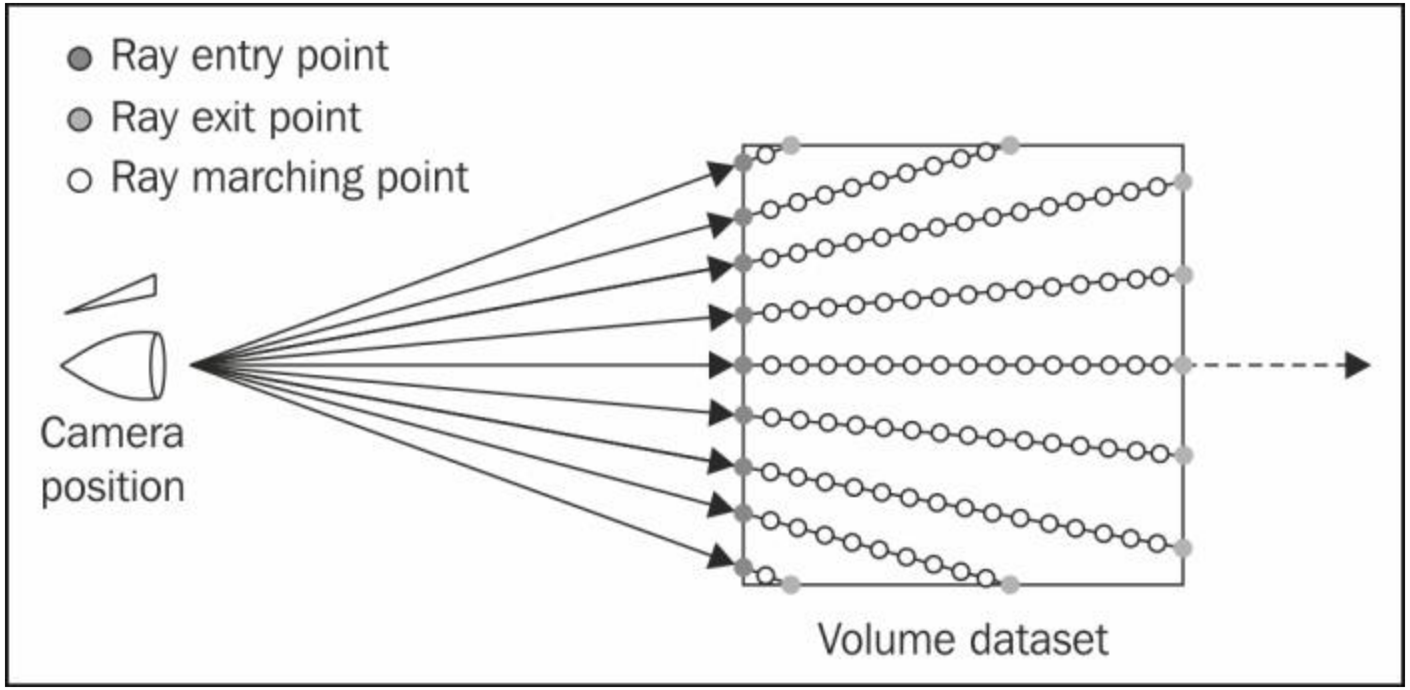
notch to the right.





Introduction

Volume rendering does not reconstruct a surface by identifying intersections of camera rays and geometric primitives, but it samples the data set in 3D by marching rays through the data set and using digital signal processing algorithms to reconstruct the original signal that has been discretized and stored in the voxel structure.



Introduction

In order to visualize and differentiate different types of tissue and bones one uses a:

- color palette
- transparency function associated to the color palette

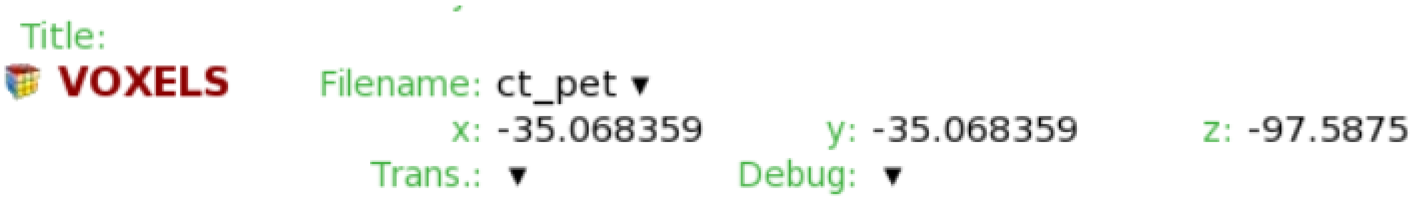
With the help of the transparency function soft tissue becomes translucent, whereas high density regions (e.g. bones) remain opaque.

Presently 3 fixed transparency functions are implemented in FARM, which in the future should become user configurable.

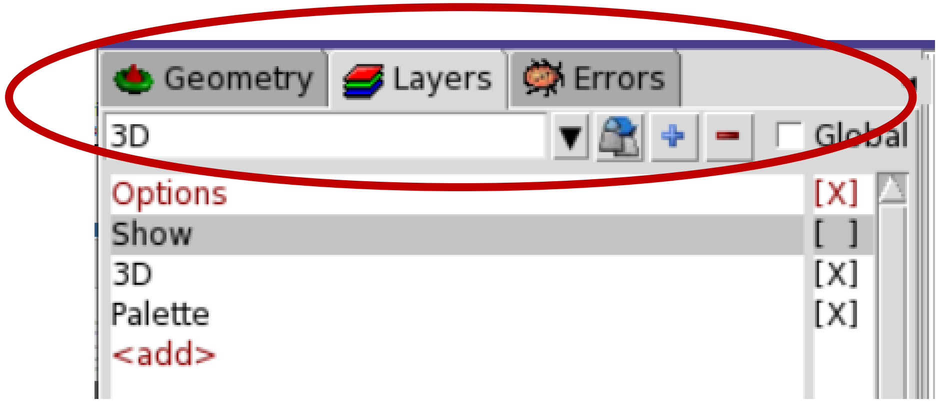
Choosing the right combination of palette & transparency function helps to visualize and emphasize different details – <u>try different combinations</u>!

Volume visualization

1.) Create a voxel card in the input and associate the voxel geometry file with it

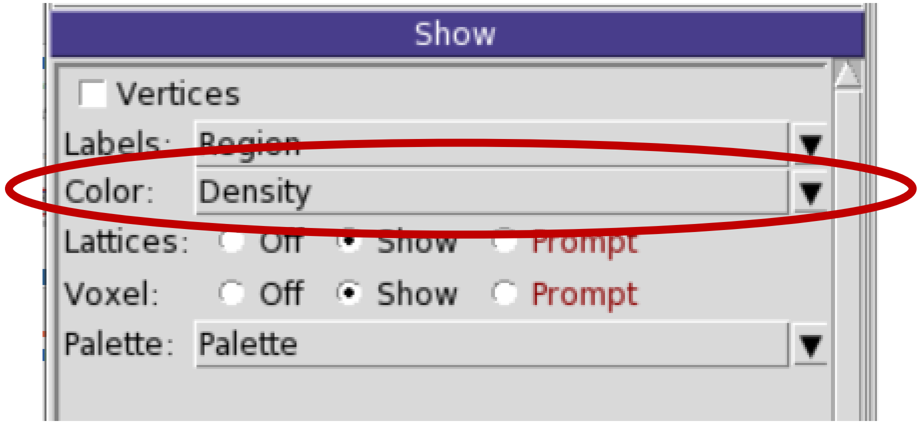


2.) Change to the geometry viewer, open the “Layers” tab and select the “3D layer” & “Show”

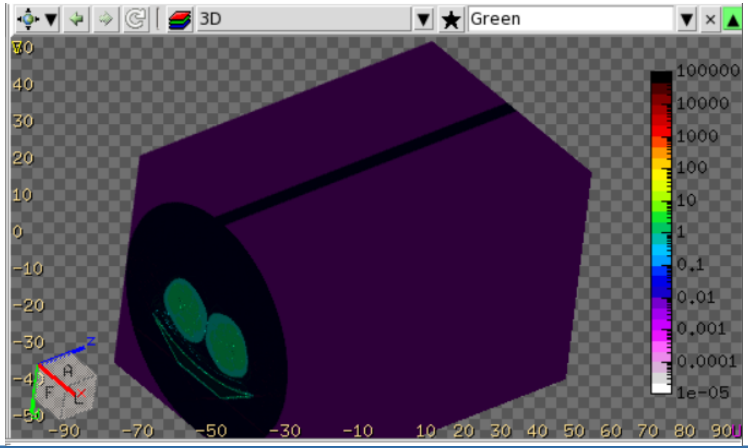


Volume visualization

3.) In the tab “Show” below associate the “Color” with “Density”



4.) In the visualization windows select the “3D view” and ensure that the implicit clipping
plane does not clip your geometry

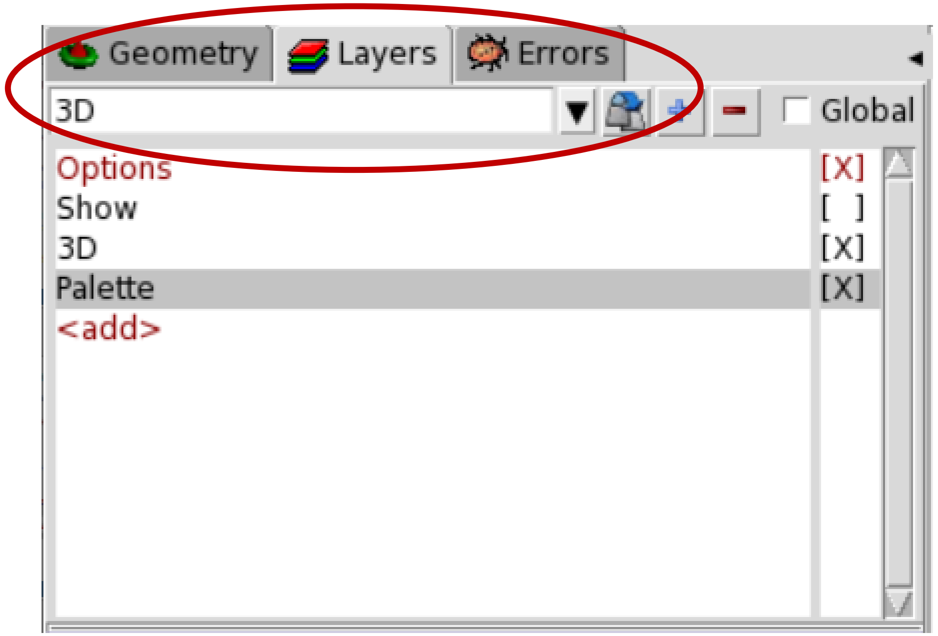


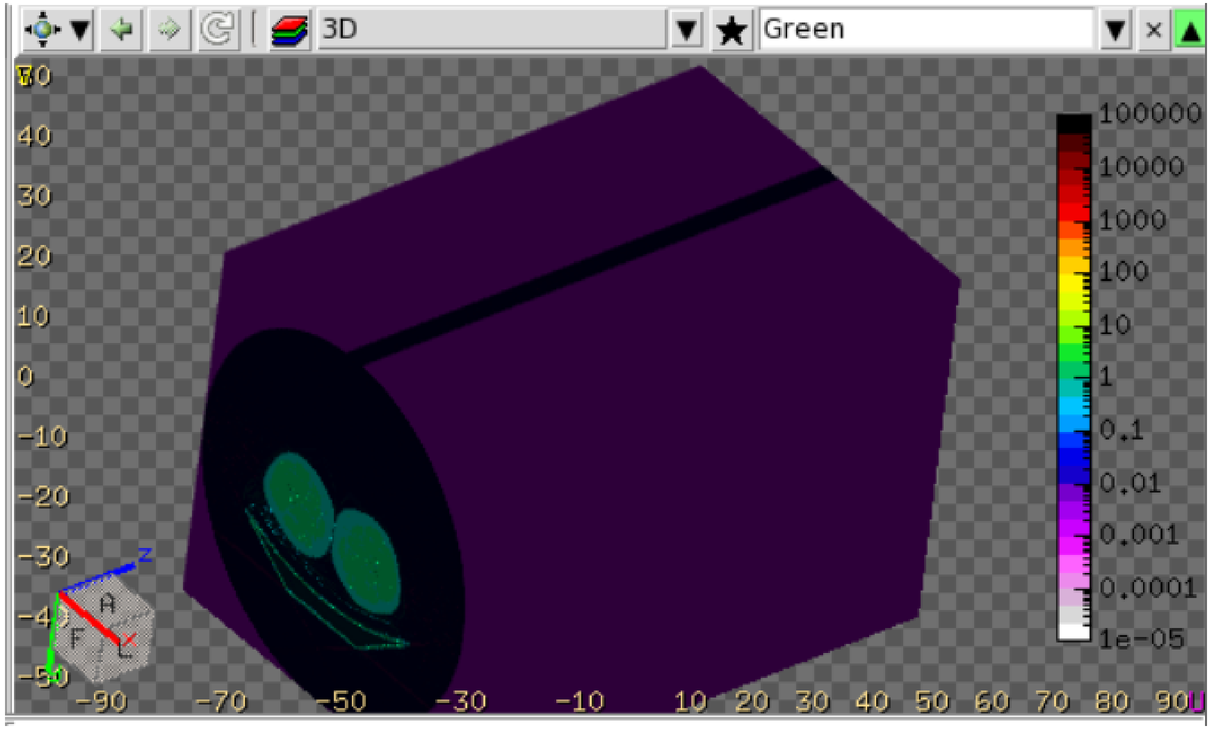
Volume visualization

5.) Setting up the palette:

By default all data (incl. air) is shown. Thus, one has to apply “cut offs” for the data.

a.) Select “Palette” option from the “Layers” – “3D” tab





Volume visualization

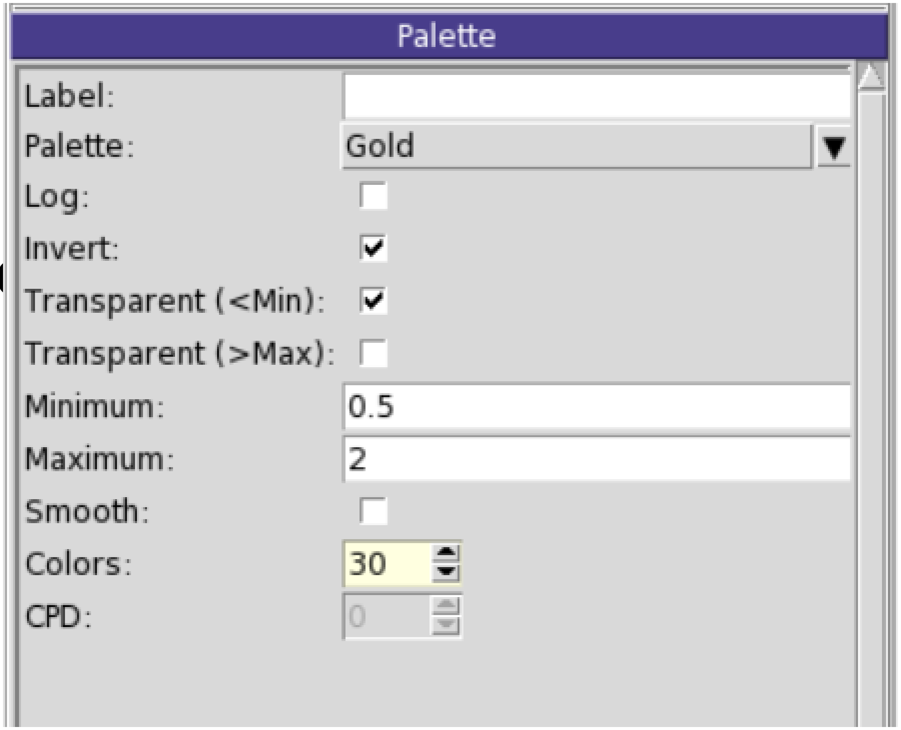
In the “Palette” dialog below select:

a.) **<u>Tick “Invert” (!!!)</u>** → dark colors best represent regions of high density(!)

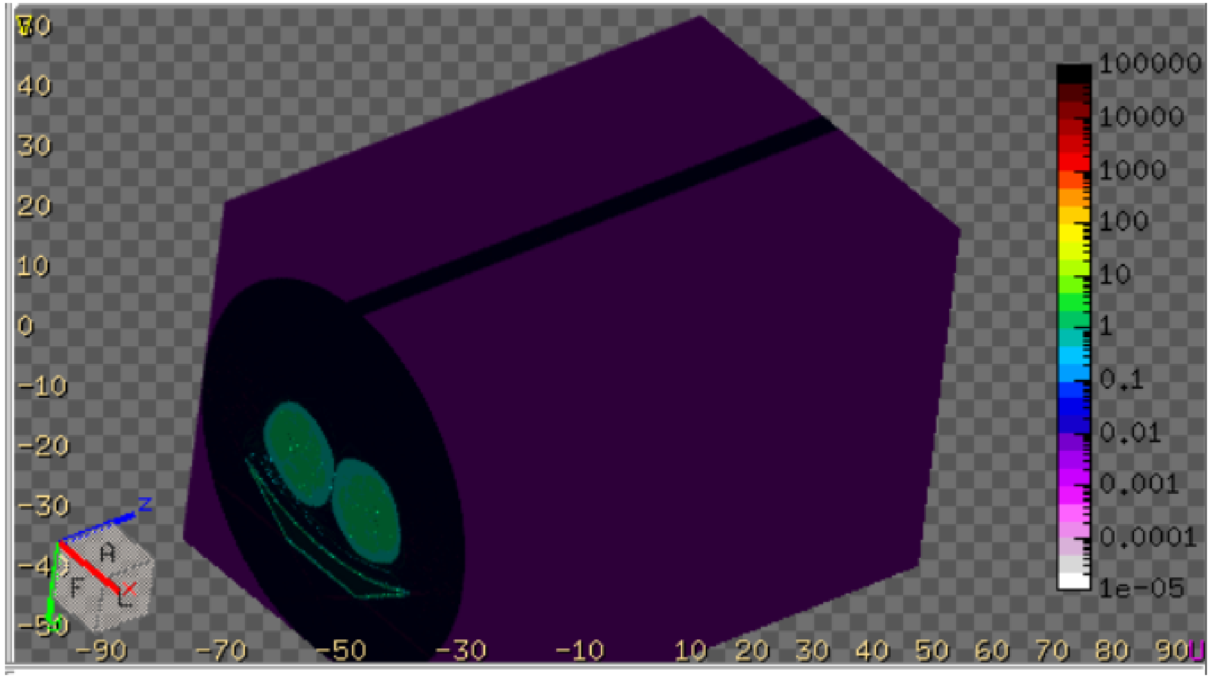
b.) Select “Transparent (<Min)”

c.) Define minimum & maximum

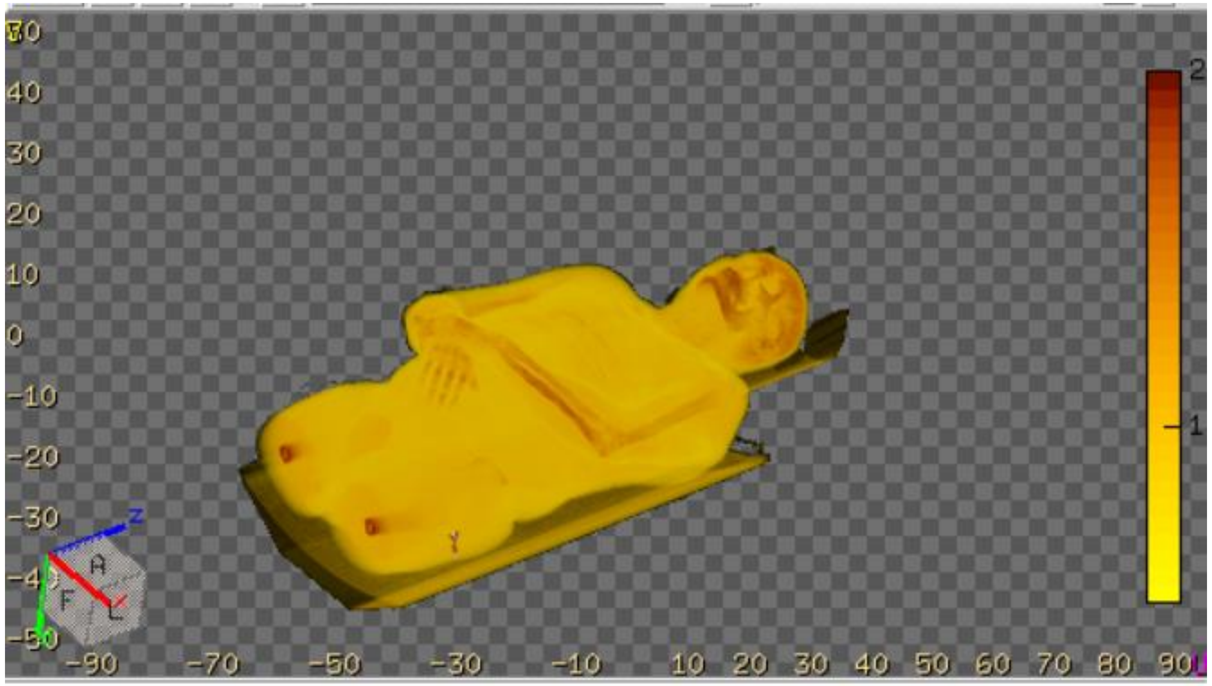
d.) Changing the selected palette will result in emphasizing & visualizing different details as the built-in transparency transfer function depends on the color.



Volume visualization

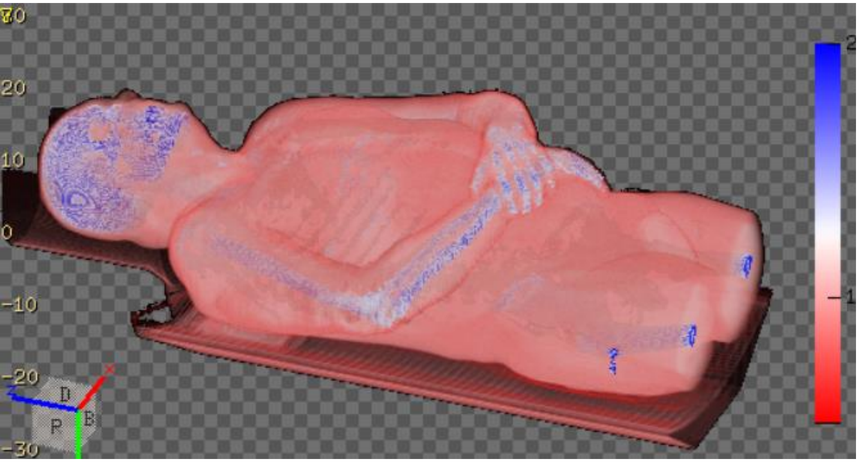


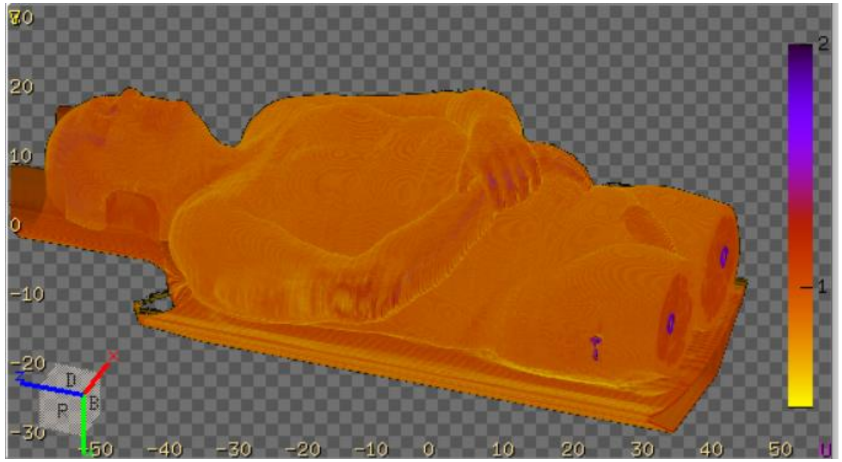
Before

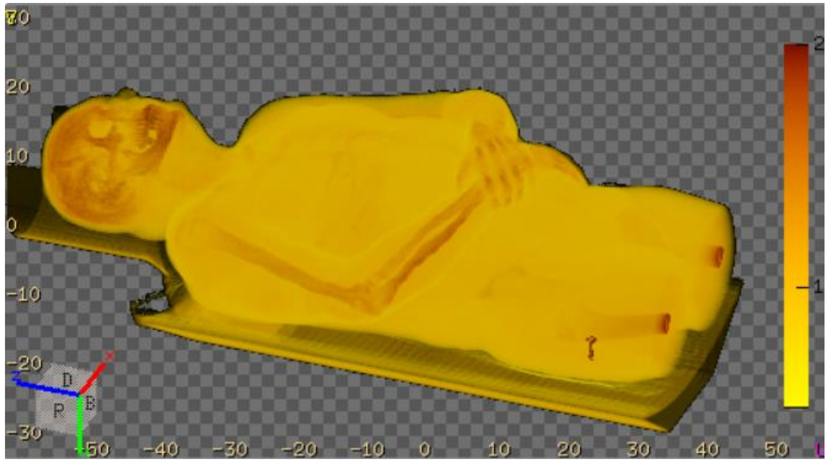


After

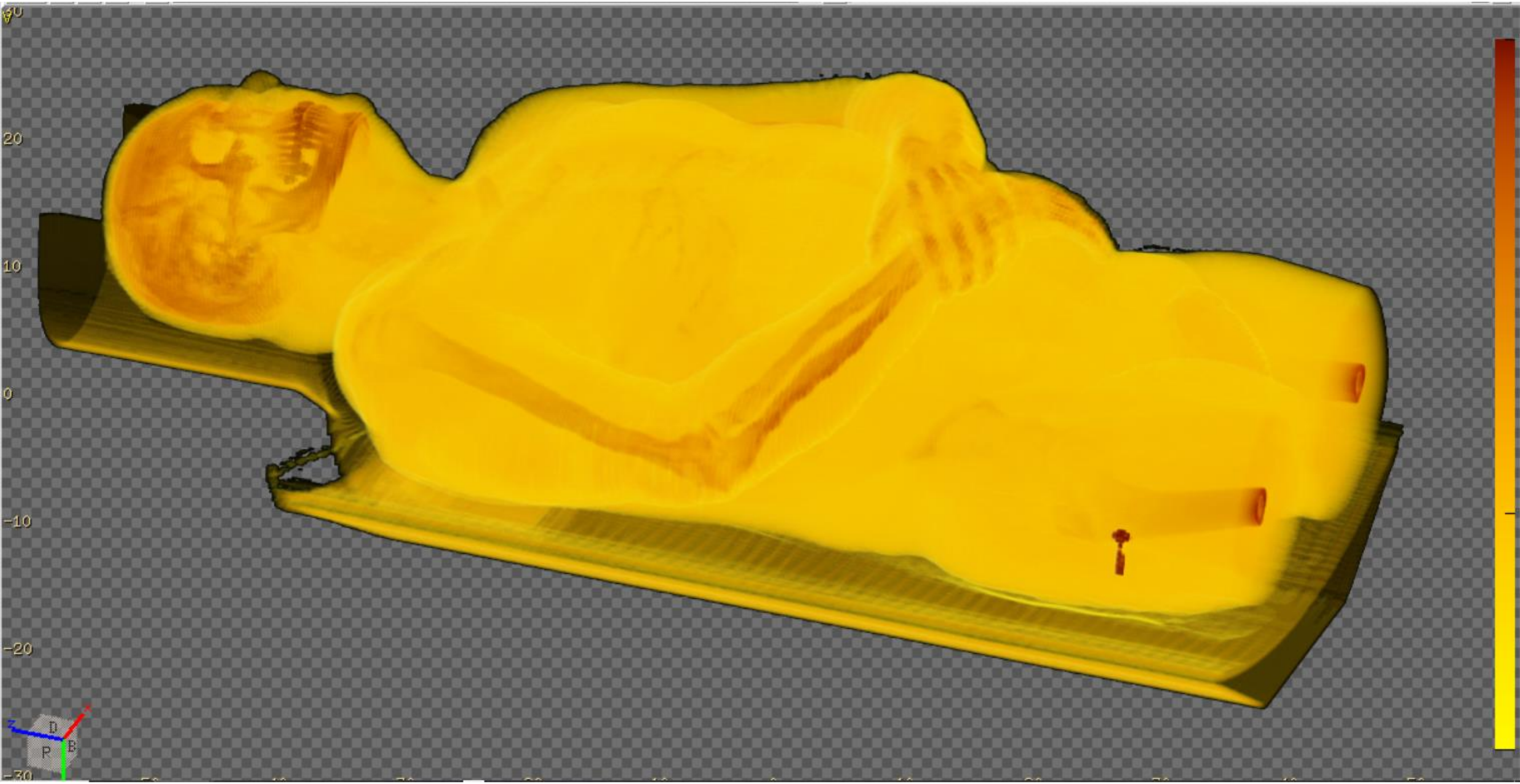
Changing the palette



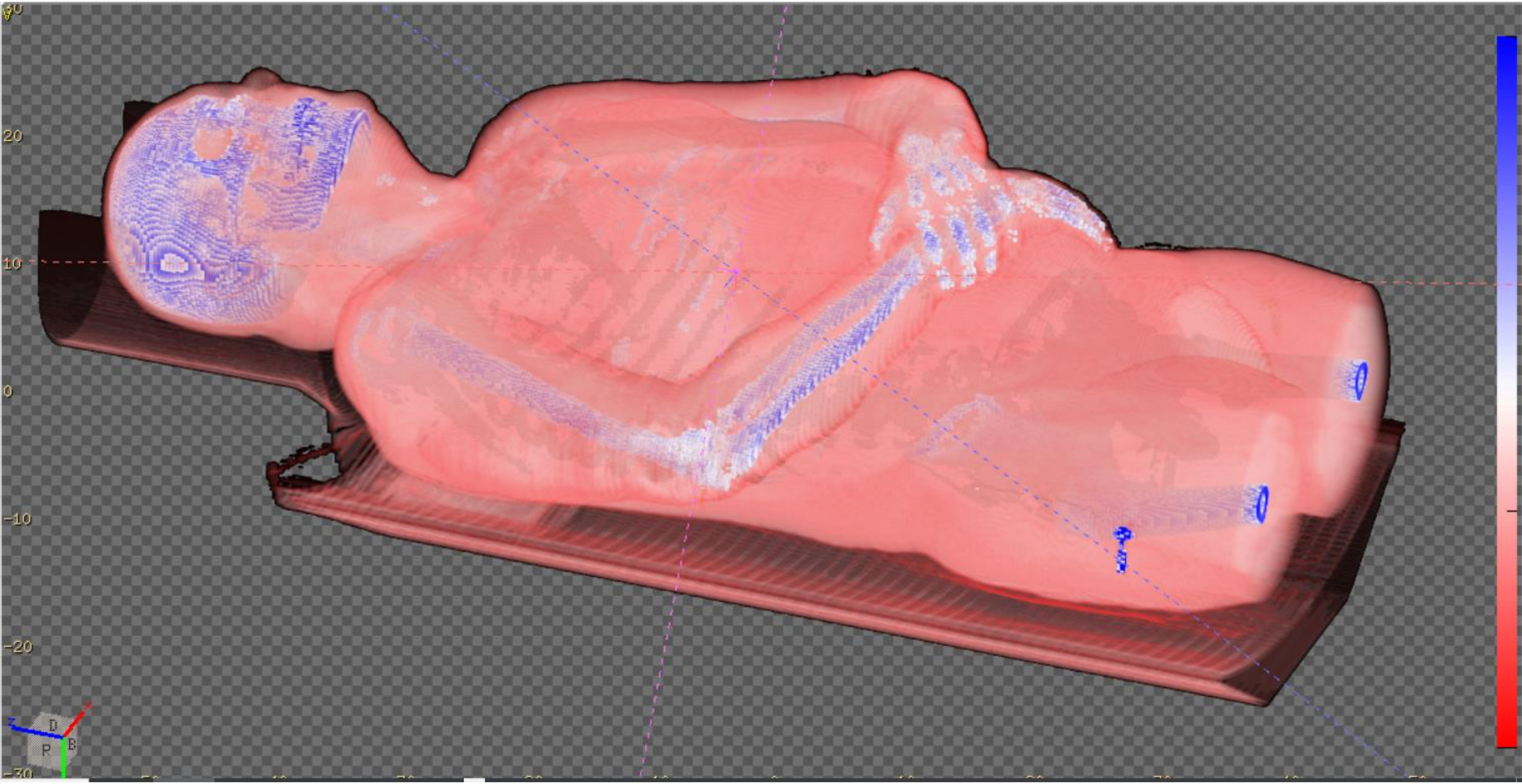




Different palette selection allows for emphasizing different details due to the associated transparency transfer function.



FLUKA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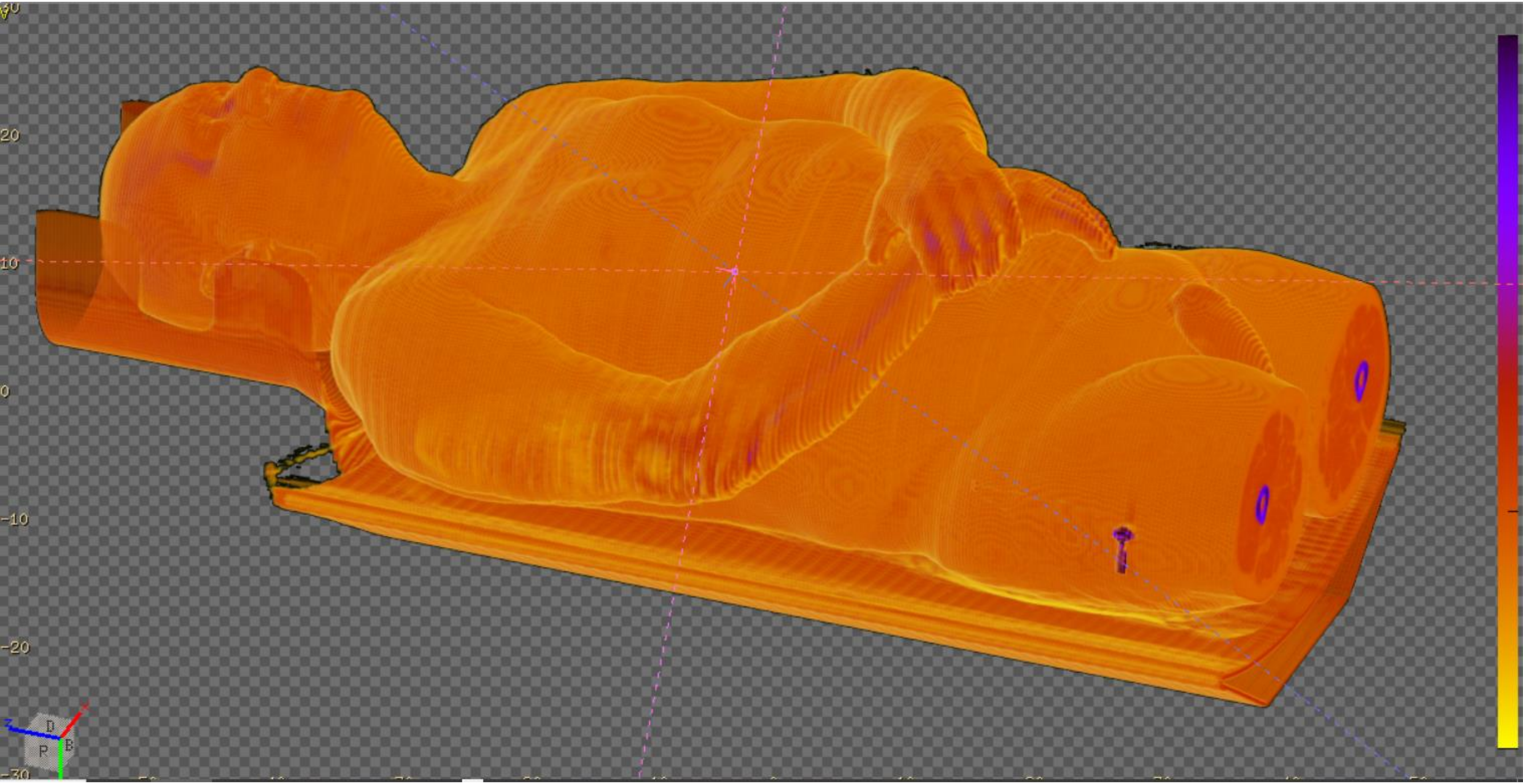

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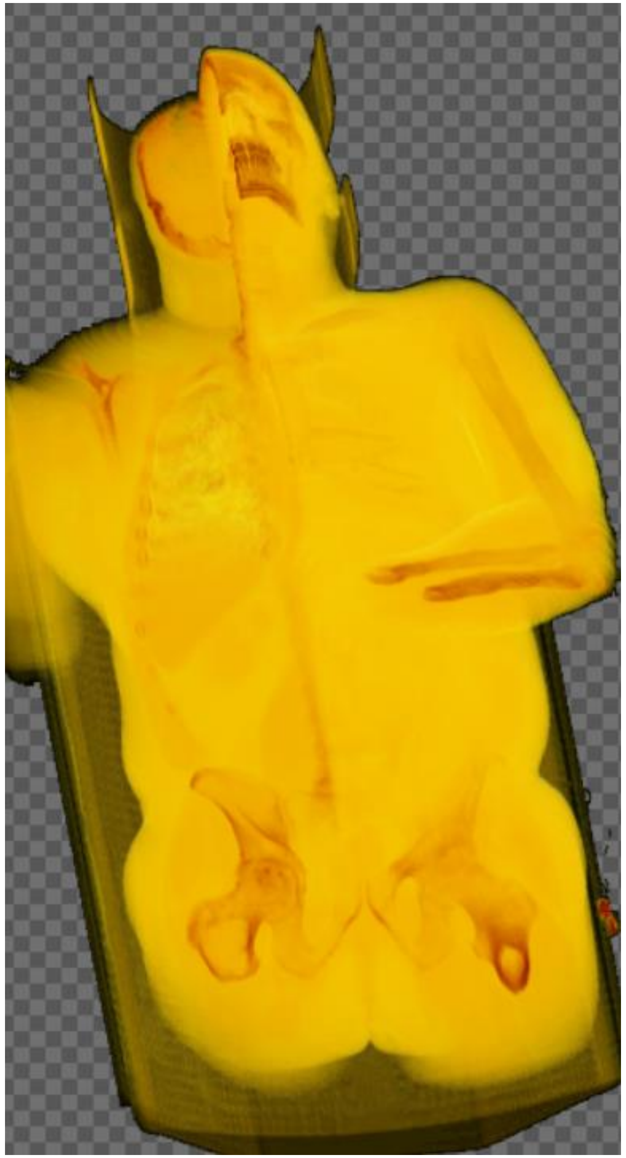
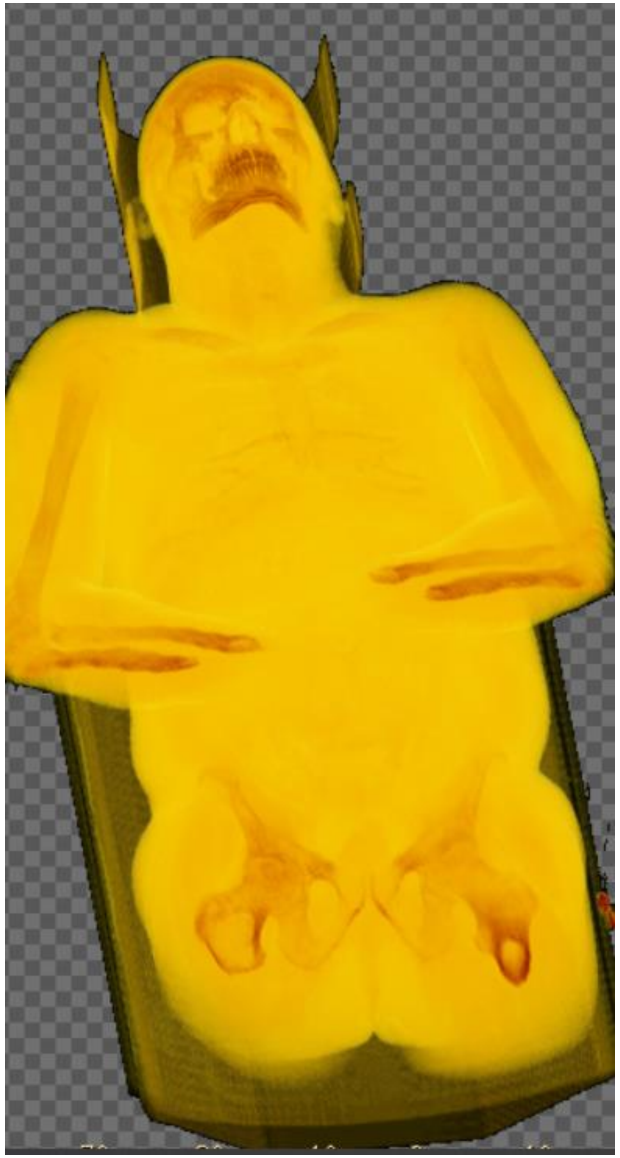
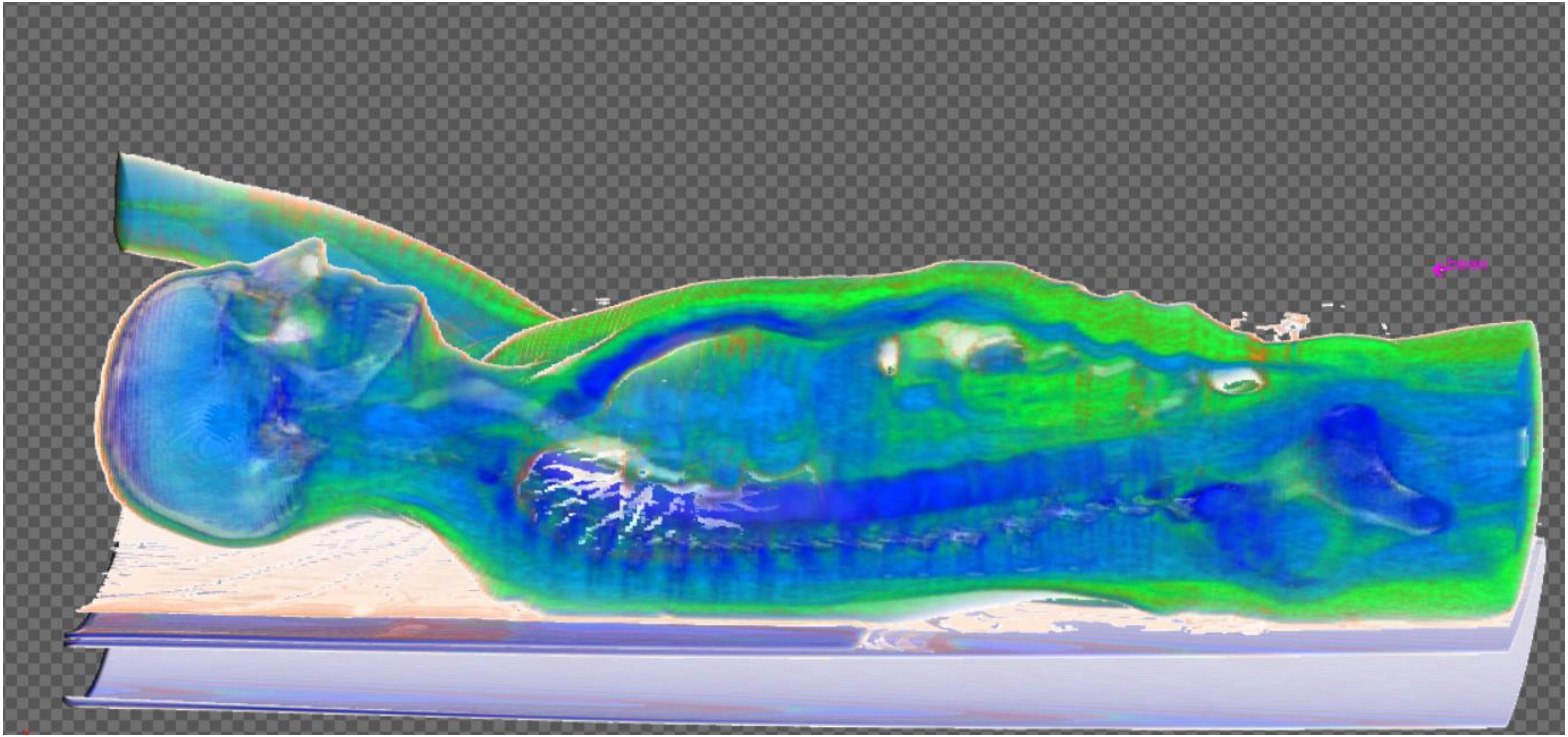


Clipping

In similar fashion as for standard 3D visualization it is possible to apply clipping planes or clipping with primitives (e.g. boxes)

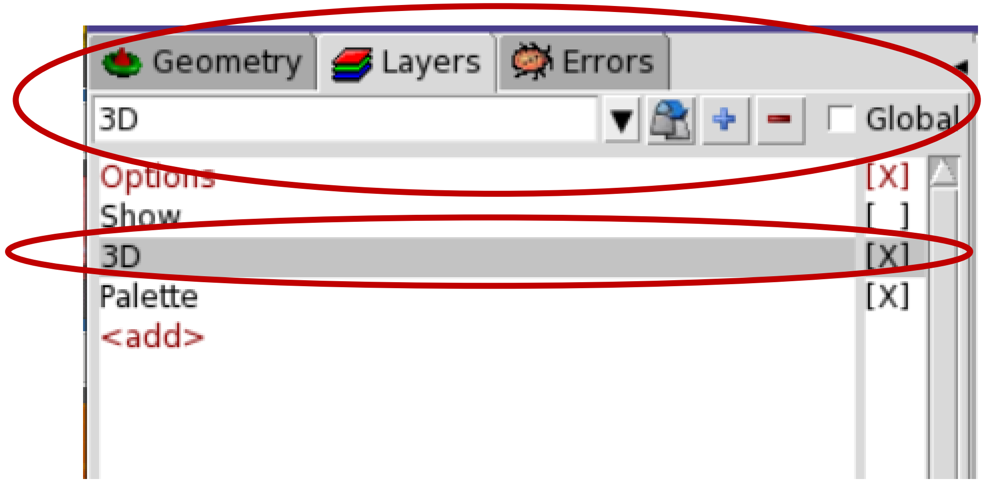


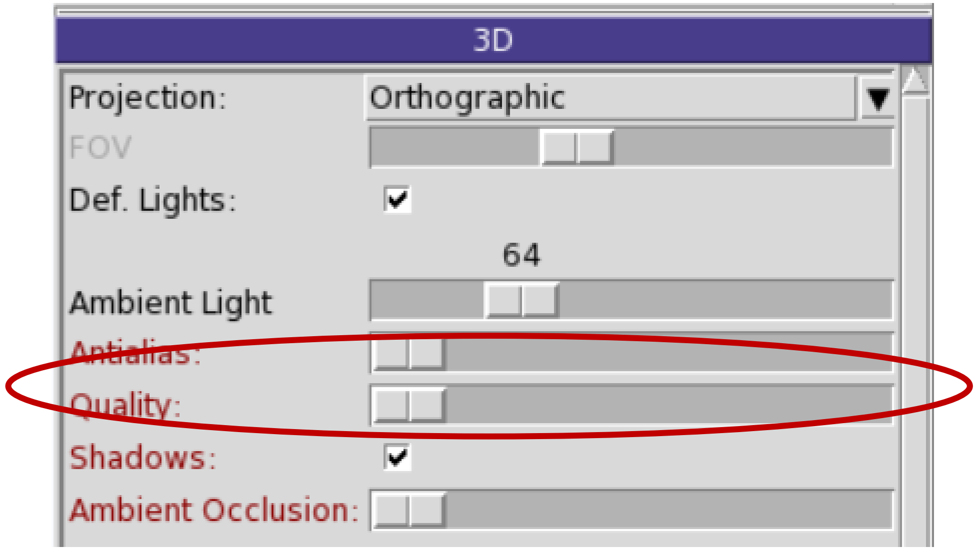
Clipping example



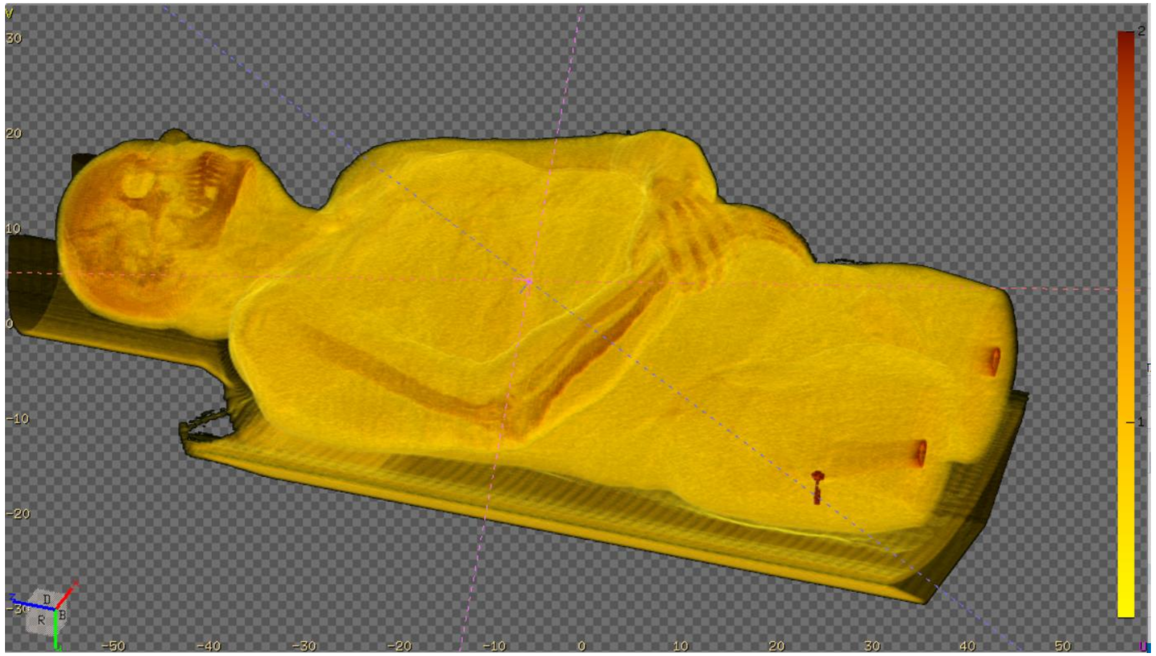
Visualization quality

The reconstruction of the original data from the discrete voxel structure can be done at 4 different quality levels. They can be selected by moving the slider “Quality” in the layer tab, after choosing the “3D” layer and “3D” option.

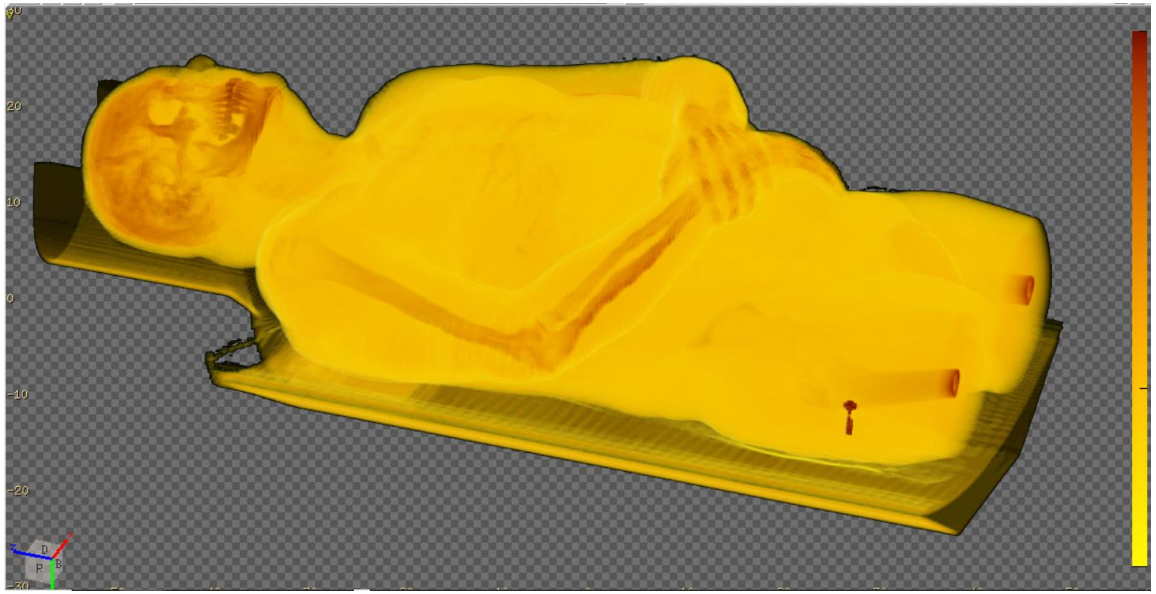




Reconstruction quality

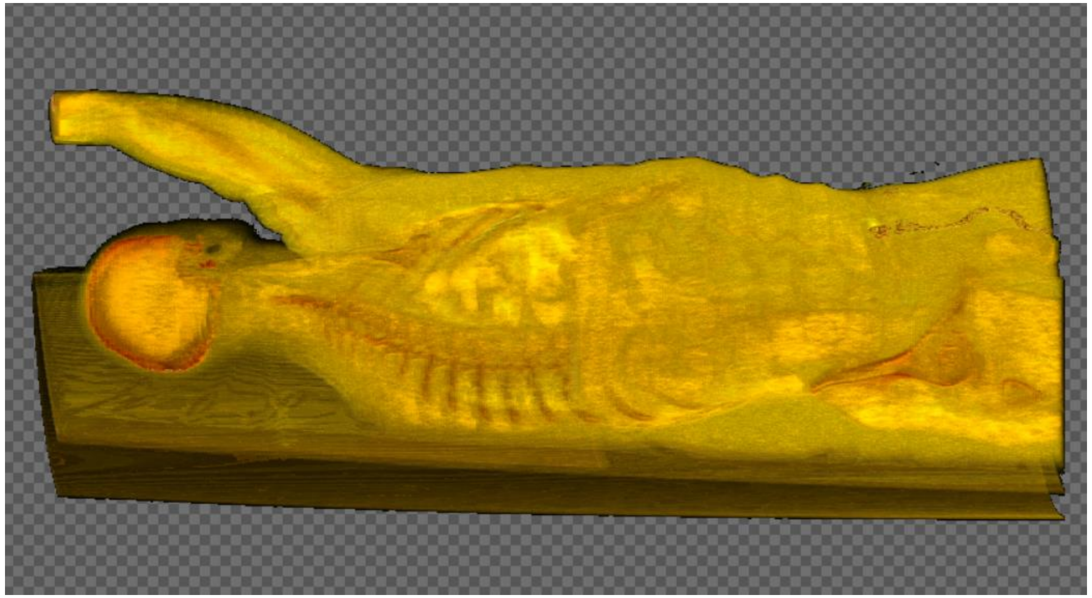


High

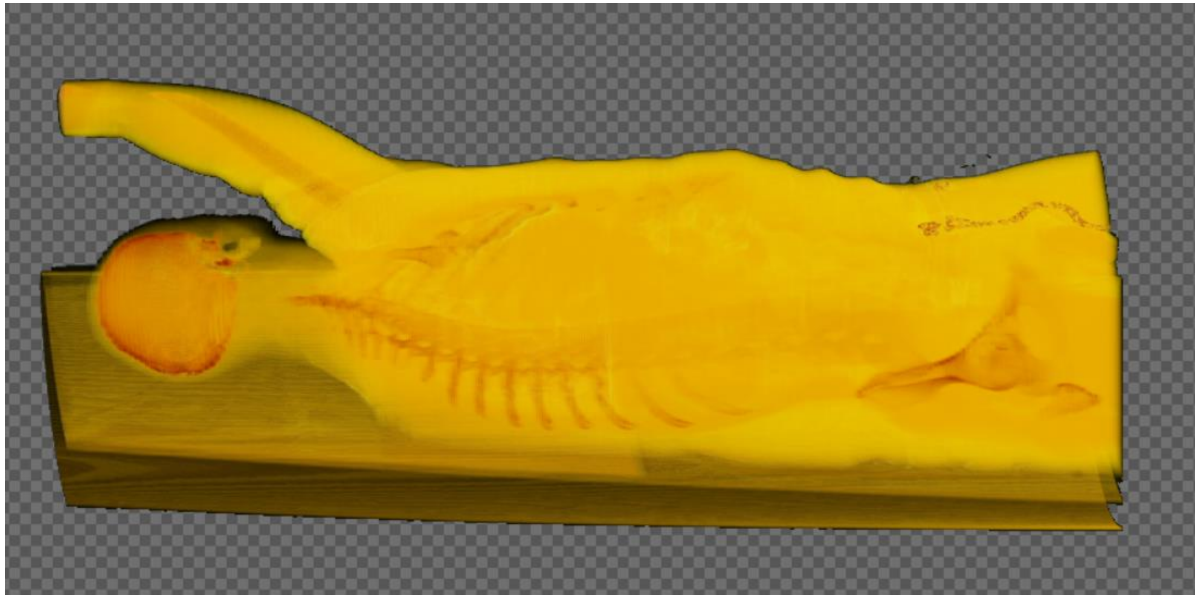


Standard

Reconstruction quality

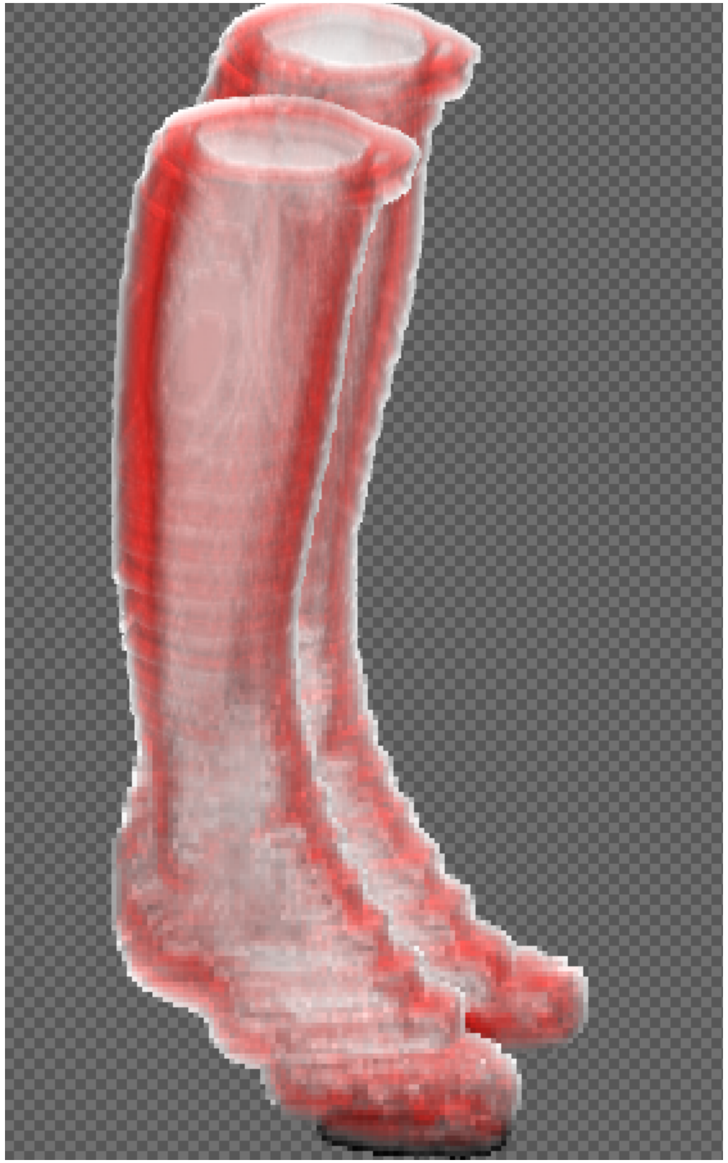


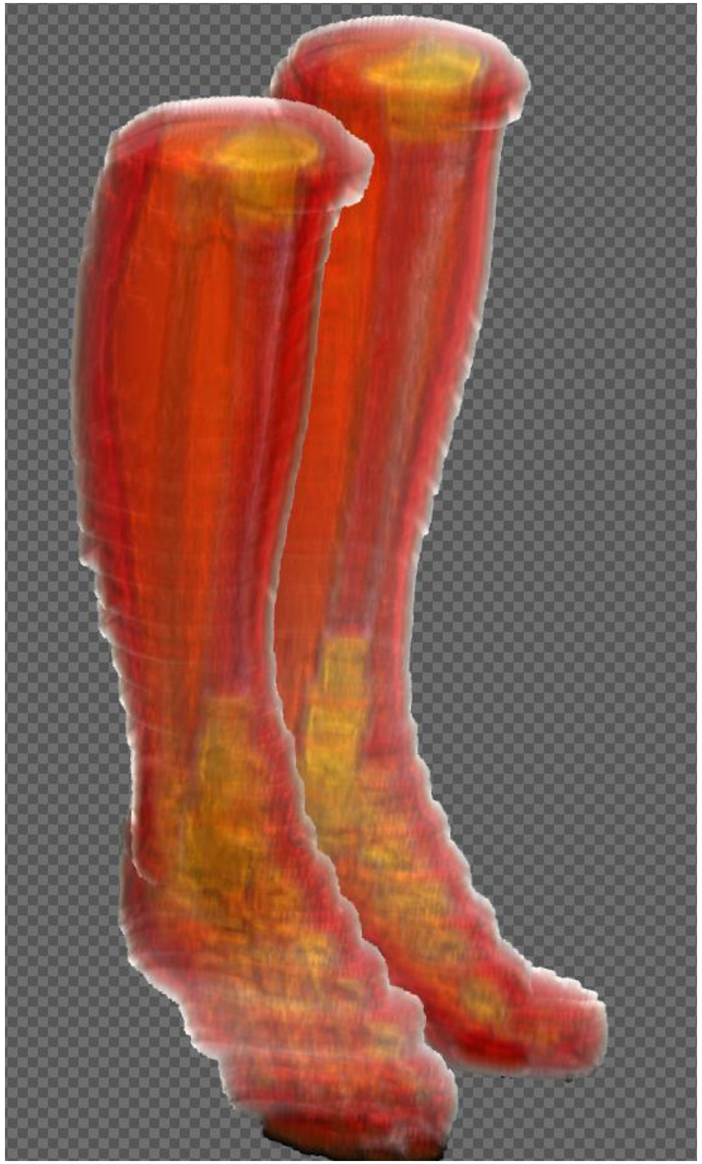
High

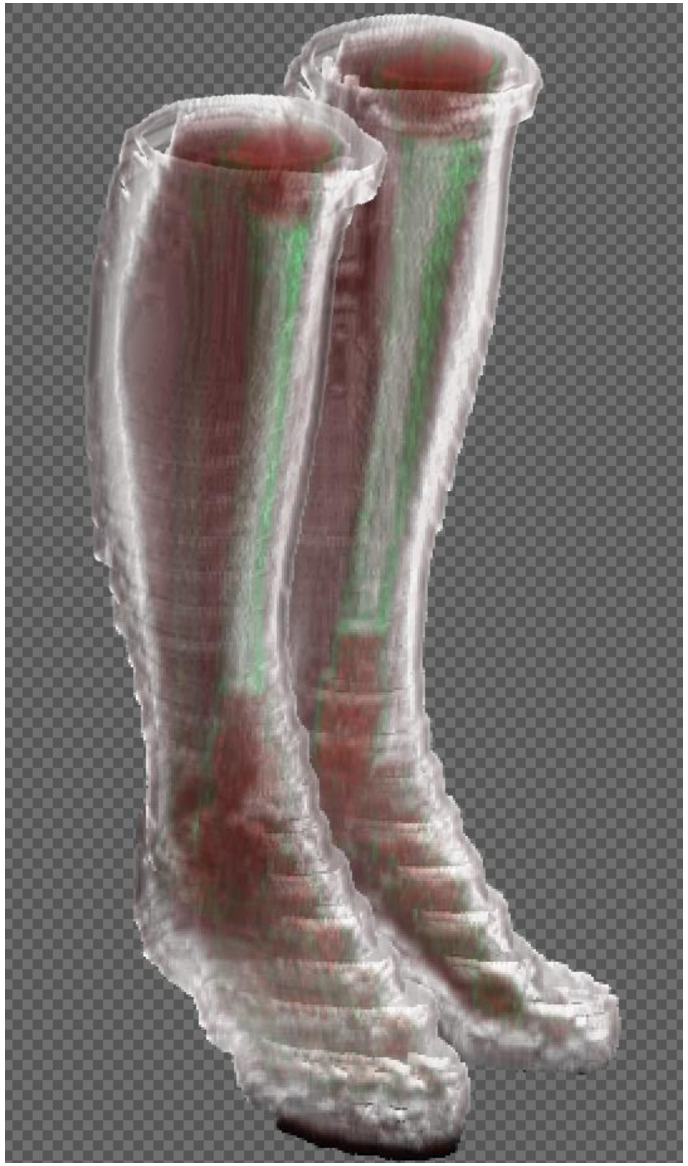


Standard

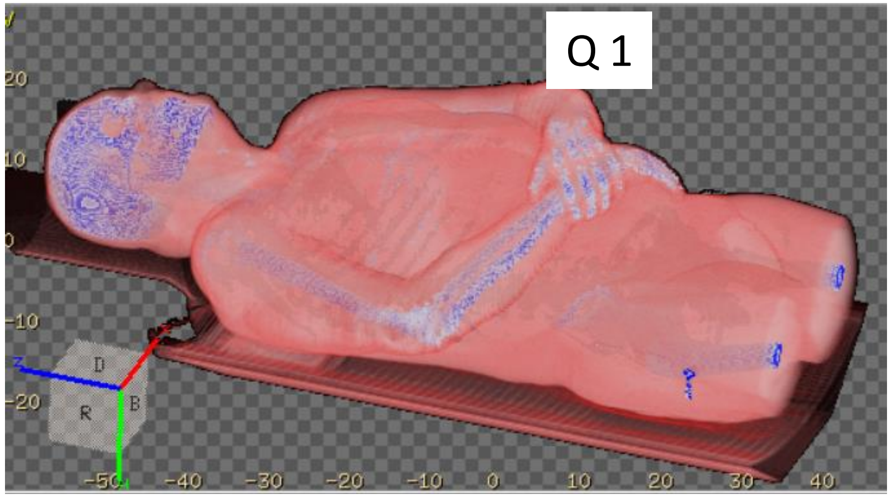
Using different palette options and color ranges to emphasize different types of tissue & bone structures

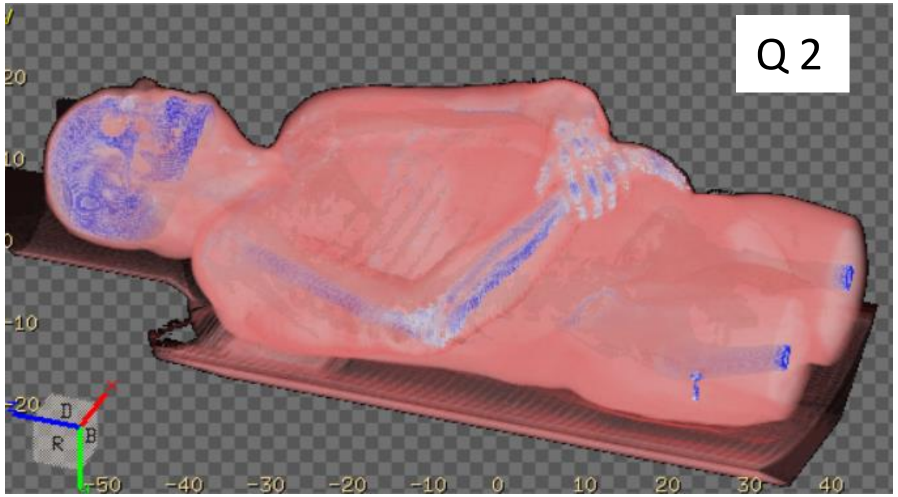


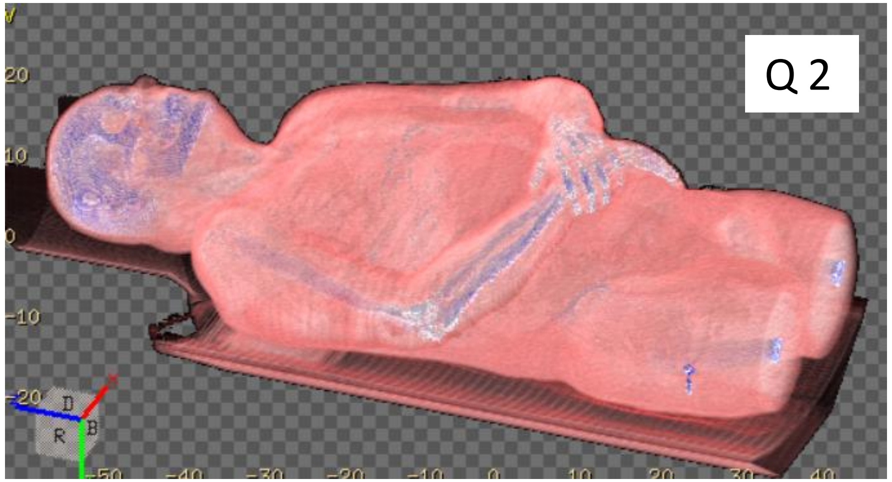


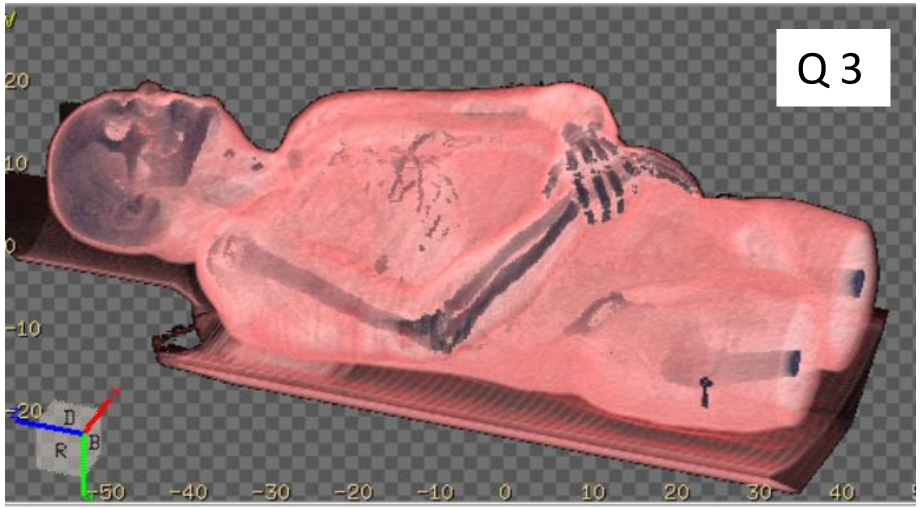


Reconstruction quality









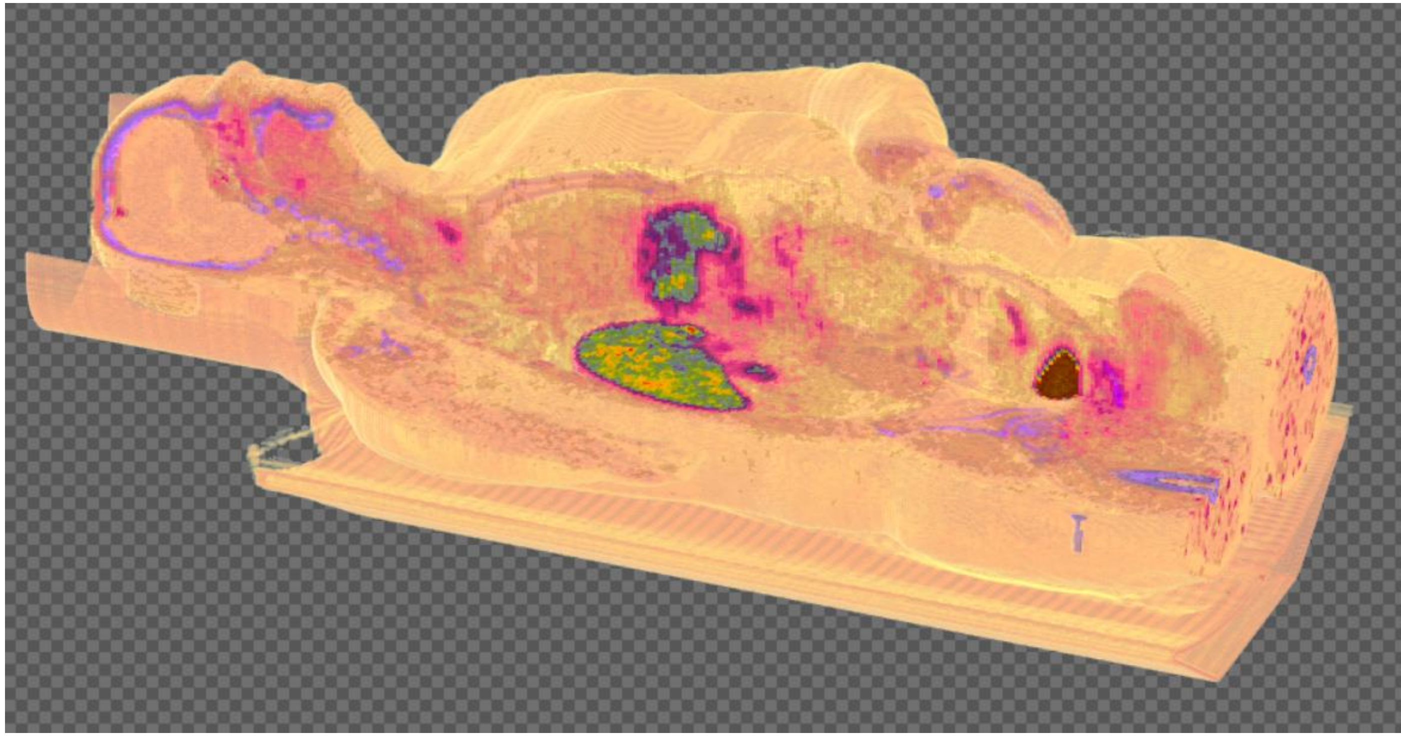
Higher quality levels exposes more details and improved contours and contrast.

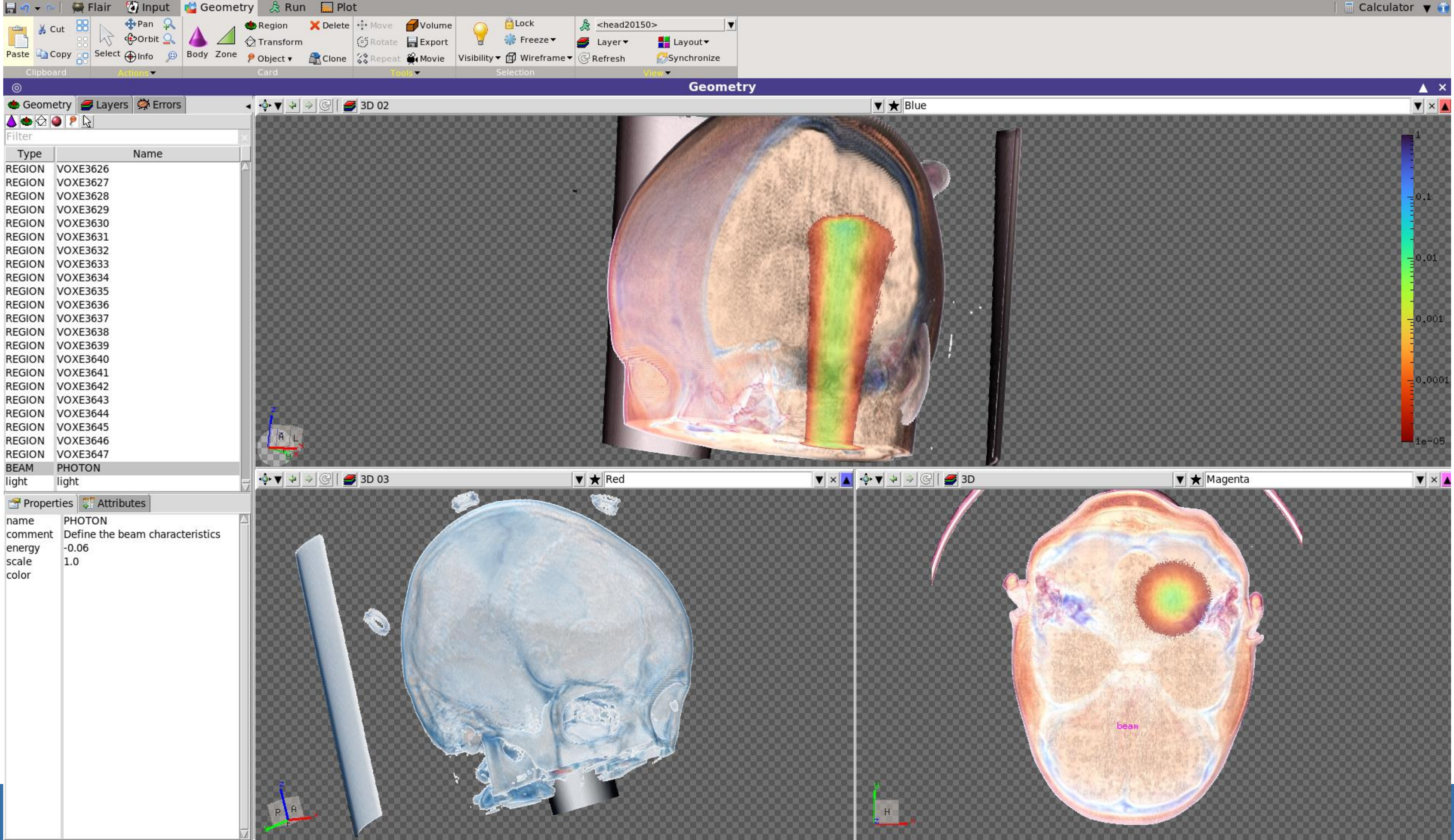
This is achieved by more sophisticated image reconstruction functions & illumination models. However, rendering times increase as well

Superposition of data

- Usrbin mesh data can be superimposed with the voxel geometry via blending and texture mapping.

- It can also be combined with clipping techniques, similarly to standard geometries





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BEAM PHOTON
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Properties
Attributes
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comment Define the beam characteristics
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scale 1.0
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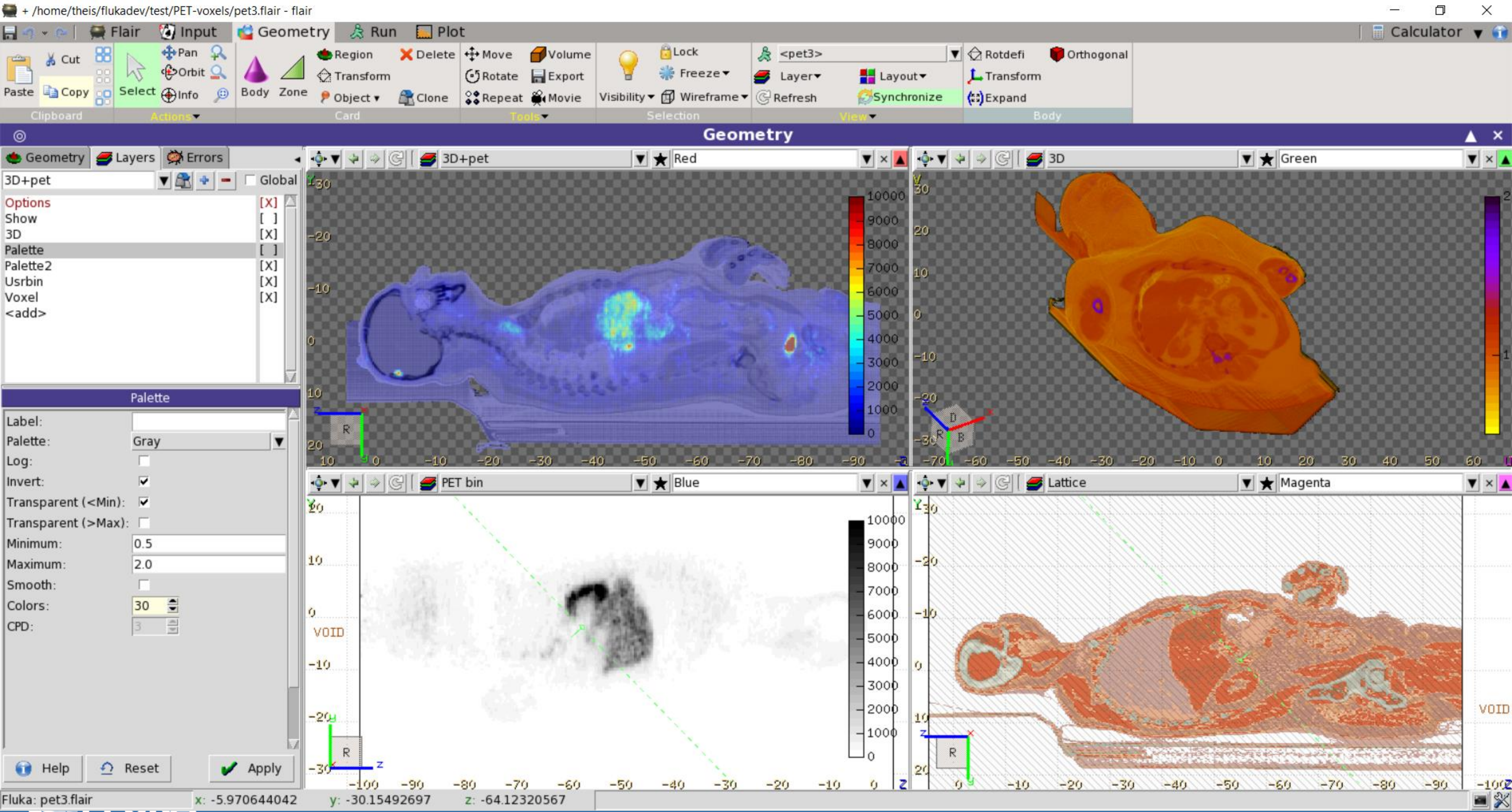
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Voxel [X]
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Transparent (>Max):
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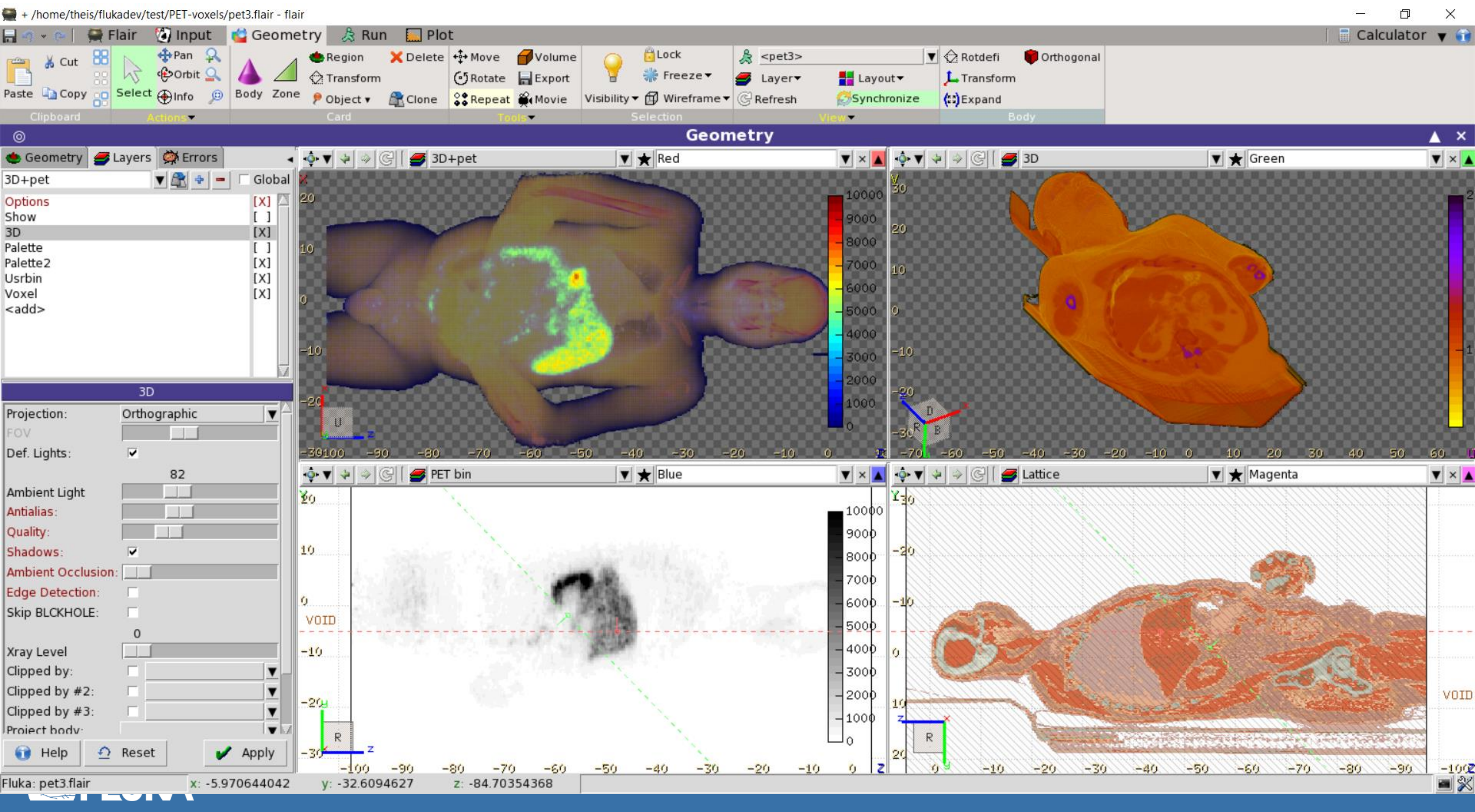
+ /home/theis/flukadev/test/PET-voxels/pet3.flair - flair
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Voxel [X]
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Ambient Light
Antialias:
Quality:
Shadows:
Ambient Occlusion:
Edge Detection:
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Clipped by #2:
Clipped by #3:
Project body:
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Lattice
Magenta
VOID
Fluka: pet3.flair
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