3-D PLOTTING CAPABILITIES IN THE VISUAL EDITOR FOR RELEASE 5 OF MCNP

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ABSTRACT

A 3D plotting capability has been added to the MCNP Visual Editor, which comes bundled with MCNP version 5. This latest release of the Visual Editor allows for the creation of a 3D image using a ray tracing algorithm. Additionally, a radiographic 3D option has been added that will generate a black and white plot that will highlight the different regions in a geometry.

Key Words: MCNP, Visual Editor, 3-D Plotting, Radiographic Plotting

1. INTRODUCTION

The Monte Carlo N-Particle (MCNP) Visual Editor[1] is used throughout the world for displaying and creating complex MCNP geometries. The Visual Editor combines the Los Alamos MCNP Fortran code with a Microsoft Visual C++ front end to provide a graphical user interface. By linking the MCNP Fortran with the graphical interface code, the MCNP transport algorithms are available to the Visual Editor to allow for advanced plotting features such as particle track plotting[2] and, in this case, 3D ray tracing.

To create a 3D image, MCNP is used to transport particles from a user specified viewpoint to a plotting plane specified by the user. Within the MCNP code is all the logic necessary to determine what cells are encountered in the ray's path. The color of the cell is set to the cell's material composition.

Because this approach uses the MCNP transport routines, it is possible to view 3D plots of any MCNP geometry including those containing lattices, universes, fills and macrobodies.

Cut-away views of the geometry can also be created by using a cookie-cutter cell, a feature which already exist in MCNP for source point rejection, to define a region to cut-away from the geometry.

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2. 3D Plotting

2.1. Generating a 3D Ray Traced Image

The use of 3D visualization is especially helpful in visualizing complex yet sparsely populated geometries. The geometry displayed in Figures 1 and 2 is a glove box used to separate a radioactive organic liquid layer in an aqueous solution. It is an excellent example of the usefulness of 3D plotting because it takes many 2D cuts of the geometry to give the user a perspective on the actual layout of the contents of the glove box.

Figure 1 shows an XY and XZ view of the glove box with the origin shifted to the most useful cut of the geometry. The Visual Editor's source point plotting capability was used to plot the starting source points on top of the geometry for the first 100,000 source particles. Source points up to 100 cm outside of the plot plane are projected onto the plot plane. In Figure 1 it can be seen that there are pipes containing the source located off the plot plane, indicating the complexity of the source and geometry.
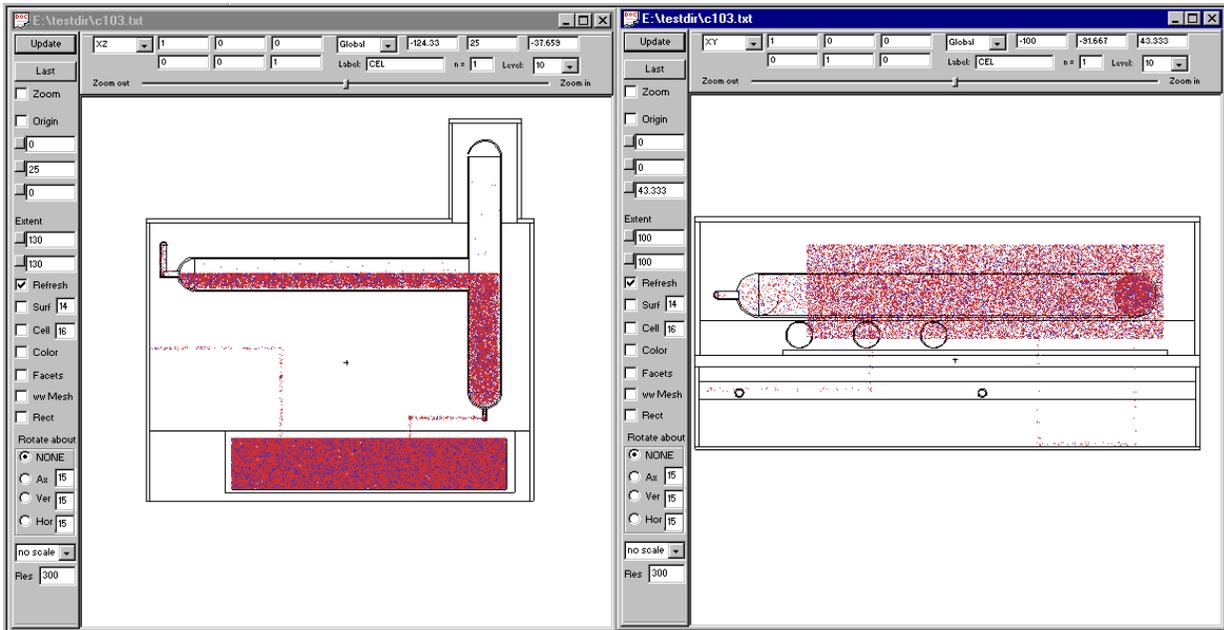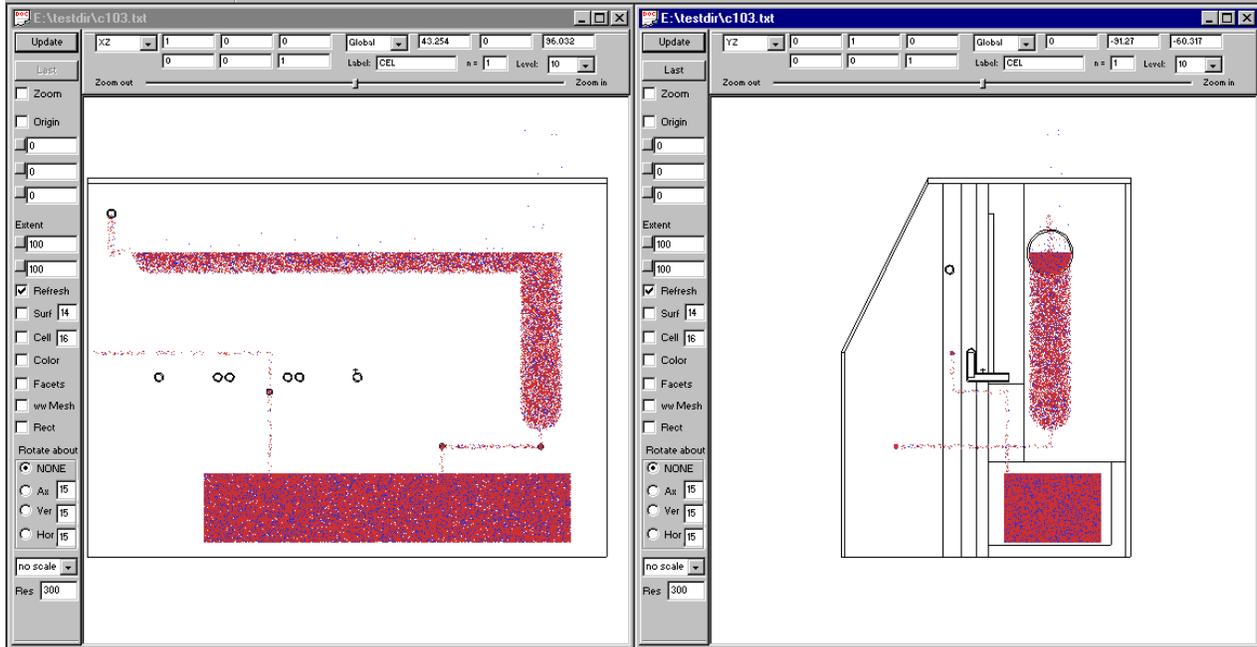

Figure 1 – XY and XZ 2D Plot

Figure 2 shows the XZ and YZ plots at the center of the glove box. The starting source points for the first 100,000 particles are superimposed on top of the geometry. Once again it can be seen that there is a lot of geometry and source complexities that can not be seen in the 2D view.

Figure 2 – XZ 2D Plot at Origin and YZ 2D Plot

To create a 3D view of the glove box, the user needs to select "3D View" from the main menu of the Visual Editor to bring up the 3D plotting window. In the 3D plotting window, the user needs to define a viewpoint. The plotting plane is determined from the 2D basis vector. The user must also specify all cells that should be rendered in 3D.

MCNP will then use its particle transport routines to send rays from the viewpoint to the plotting plane. The particles are sent on a directed path from the viewpoint to a 2D plane that is defined by using the basis vectors and extents on the 2D plot. This allows the user to set up the 3D view using the 2D window parameters. The first of any of the user specified cells encountered between the viewpoint and the small area (defined by the resolution parameter) on the plotting plane is plotted. The color is taken from the object and shading is determined from the angle of incidence when the particle encounters the object.

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Figure 3 shows a 3D image of the glove box. The many pipes inside the glovebox can be seen. The blue cells contain the radioactive source and represent the locations of the points plotted in Figures 1 and 2. The green cells represent non-radioactive aqueous solution. The remaining geometry was included in the model to account for its effect on the shielding.
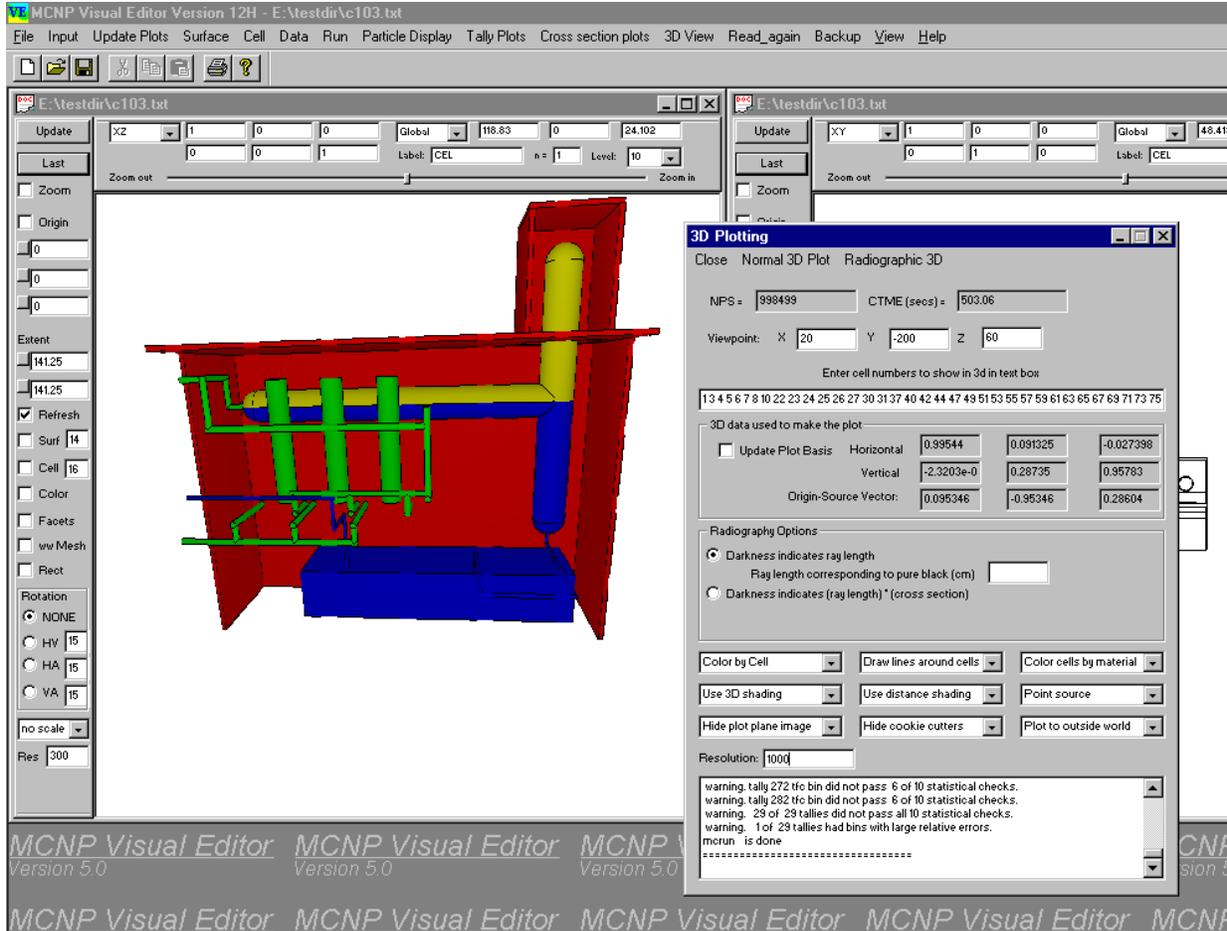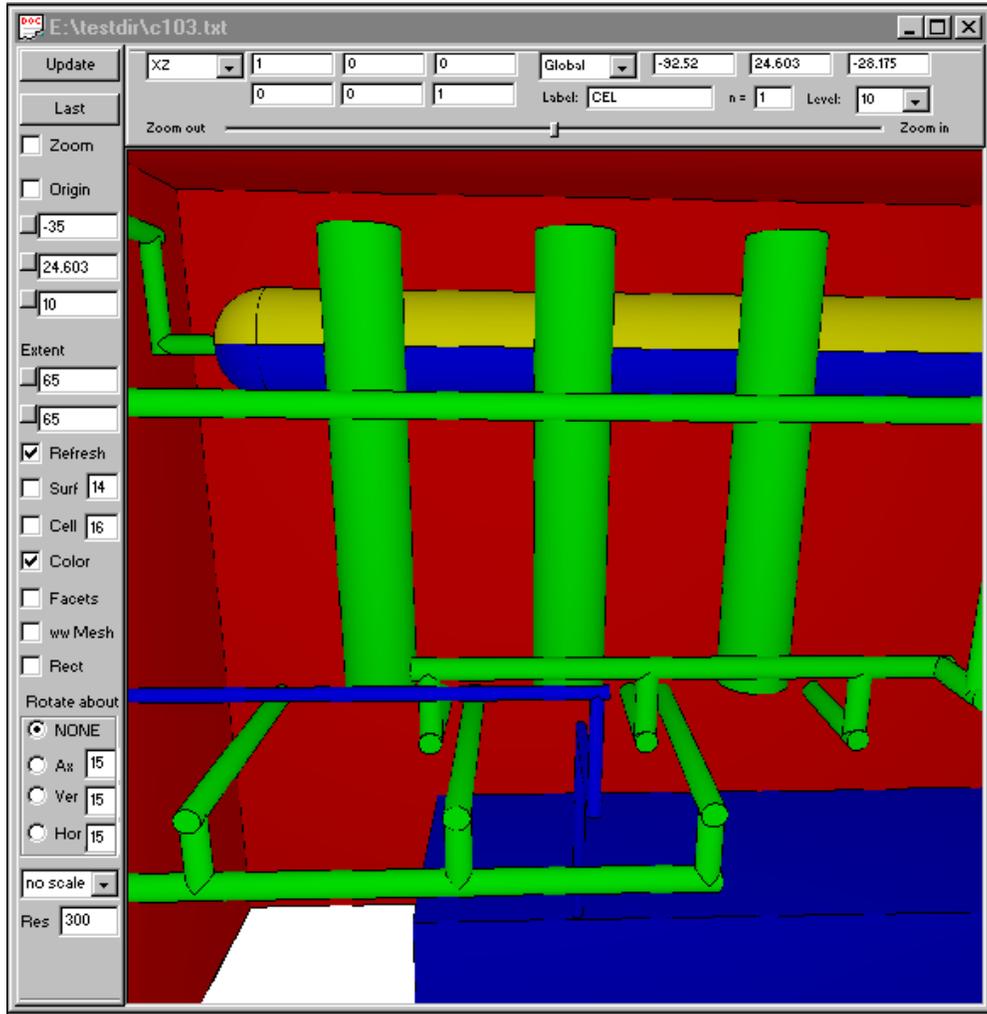

Figure 3 – 3D Plot of Glove Box

Figure 4 shows a close up view of the pipes located inside the glove box. A plane source with a viewpoint of -40, -90, 40 was used to make the plot in Figure 4.

Figure 4 – Close up View of the Pipes in the Glove Box

Because this approach uses the existing MCNP transport routines, it is inherently compatible with MCNP. Any geometry that runs in MCNP can be displayed in 3D by the Visual Editor and any new functionality added to MCNP's geometry capability will automatically be available to the Visual Editor.

Similarly, restrictions inherent in running MCNP also apply to creating 3D plots with the Visual Editor. Partial input files will not work. The input file must be complete and functional or the 3D ray tracing will not work.

2.2. Setting the Viewpoint and Plot Plane

The menu in Figure 5 is obtained by clicking on the 3D View menu option on the main menu bar. To create the plot, the input file was read into the Visual Editor and visualized as shown in figures 1 and 2. The plot showing the XZ view (Figure 1) was used as the view, providing the basis vectors and extents, for generating the 3D image. The Visual Editor will modify the basis vector so that it is perpendicular to the viewpoint. The actual basis vector used for the 3D plot is shown the section labeled "3D data used to make the plot". If the "Update Plot Basis" checkbox is selected, then the basis vectors of the 2D view are updated to use the modified vectors used in making the 3D plot.
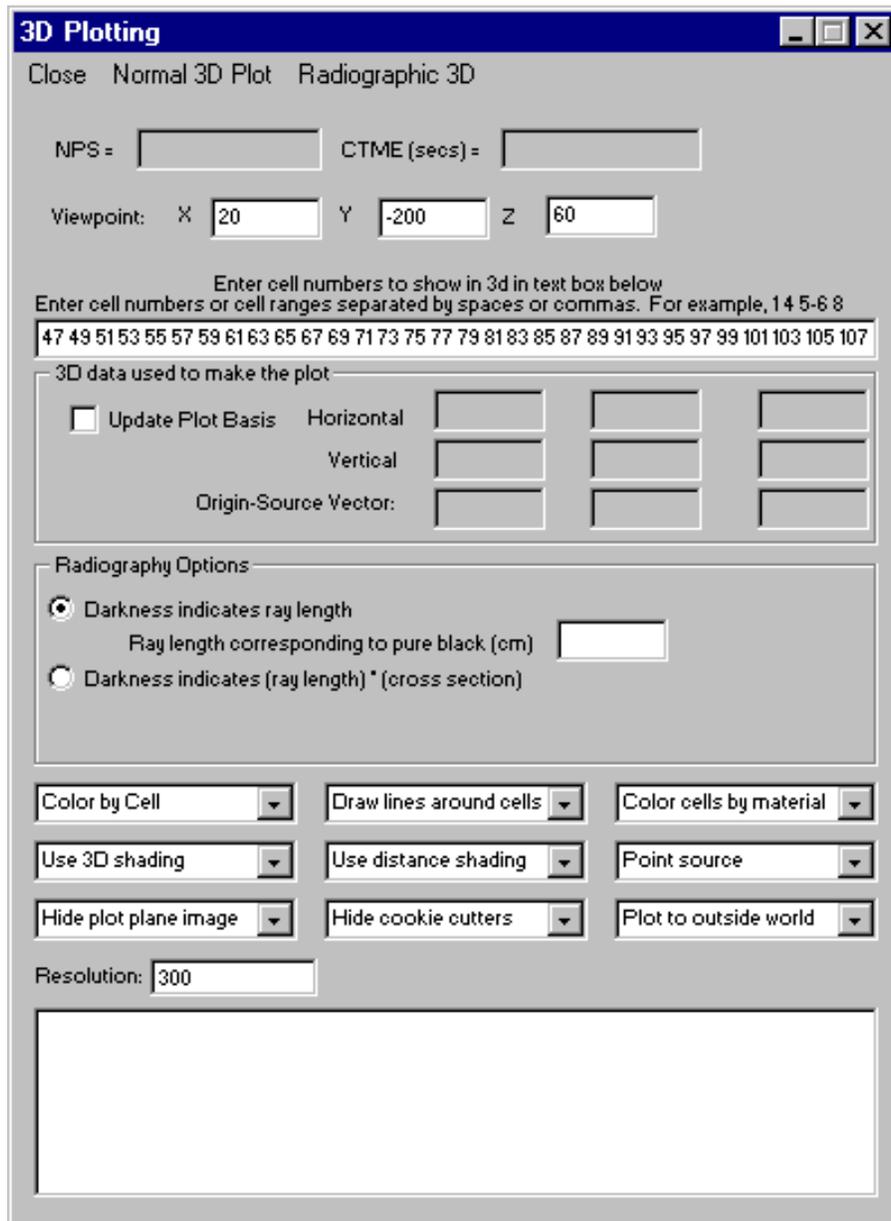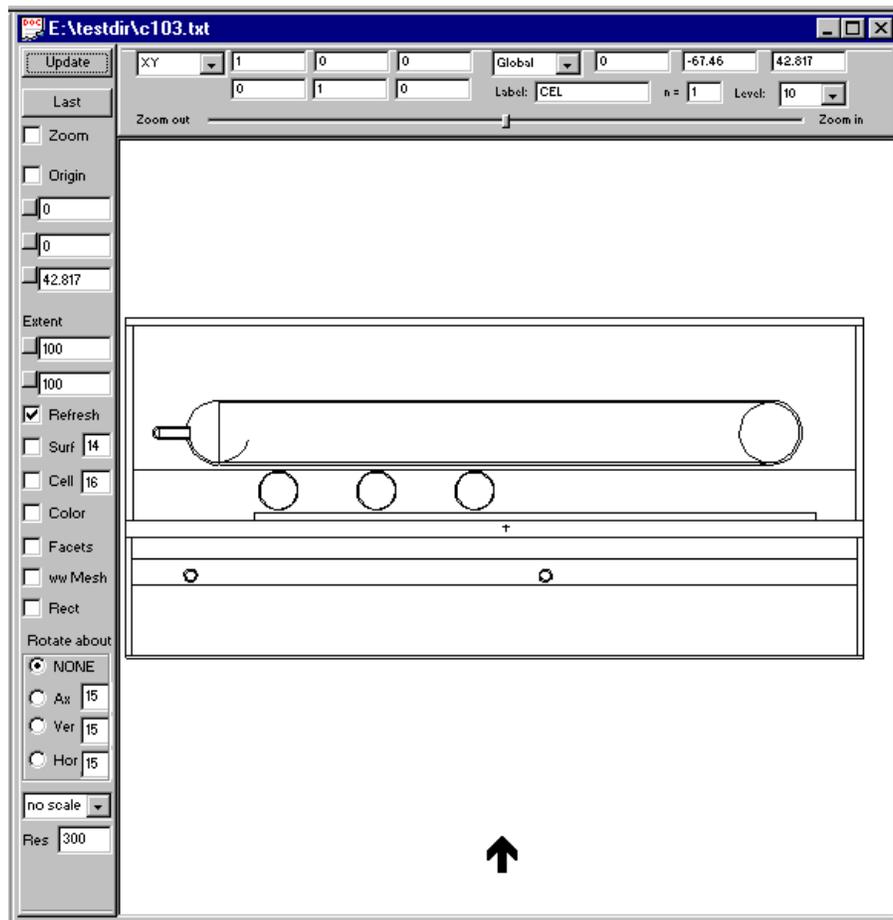

Figure 5 - 3D Plotting Menu For Plotting Of Glove Box

All the cells to be plotted are entered in the cell numbers box. Individual cell numbers are separated with a space or a comma, a range of cells can be selected using a dash. For the plot in Figure 5, all default options were used except the resolution, which was set to 1000 instead of the default of 300.

Figure 6 shows how the viewpoint was determined.   For making the 3D plot, a viewpoint of 20, –200, 60 was used. You can use the mouse cursor to show where the viewpoint should be. The arrow in Figure 6 shows the approximate location of the cursor at the time the screen shot was taken. The cursor coordinates are displayed in the three top right boxes of Figure 6. Notice that the Y value is approximately –67. To get a better perspective of the whole glove box, the viewpoint was moved back to a Y value of –200. The X value of 20 allowed the view to be rotated slightly and the Z value of 60 moved the viewpoint up to look down on the object. An error is generated if the viewpoint is located in a cell with an importance of zero or if it is on the 2D axis the 3D view will be plotted against (e.g. a Y value of zero would have produced an error).

Figure 6 – Viewpoint for 3D Plotting Of Glove Box

In some cases, plotting all cells would be advisable but it is often the case that a more useful plot is obtained by plotting only items of interest. It was determined that the items of interest were

the radioactive and organic materials and not the stainless steel that contained them. This allowed for a more meaningful coloring of the plot as the colors differentiated between the radioactive and the organic substances. Had the stainless steel been included, the plot would have been exclusively red because red was assigned to the stainless steel.

While experimenting with the rotation and content of the plot, the resolution used was 100 because the plots are produced faster. The final plot used in this paper had a resolution of 1000 to generate a better image.

2.3. Different Options Available for 3D Plots

The 3D window has a number of options that can be set to change the appearance of the ray traced image. These options are located near the bottom of the 3D plotting Window.

The "Color by Cell" option is the default option and it will set the color to be that corresponding to the material in the cell that is encountered. This can be set is to "Color by Surface," which will color each surface using a different color. For some cases this will provided better differentiation between the surfaces of cells that all contain the same material.

Additional options exist that will turn off the black outline that is drawn around the cell and will define the source as a plane instead of a point to simulate an infinite viewpoint. An option also exists to "Show cookie cutters" to generate cut-away views of the geometry.

3. Cookie-cutter Cut-Away Views

Because objects displayed using the Visual Editor often have many layers of shielding, the most helpful view is often a 3D view with a section "cut-away" to display the content of the layers. Cut-away views of the geometry can be created by using a cookie-cutter cell to define a region to cut-away from the geometry. Cookie-cutter cell capability already exists in the MCNP code for source point rejection, but it is convenient to borrow this capability for creating cut-away views.

3.1. Using Cookie-cutters in MCNP

In the Visual Editor, a cookie-cutter cell can be defined to ignore the space inside the defined region when generating a 3D plot. The cookie-cutter cell must be the last cell defined in the geometry and must not be bounded by surfaces that are used for any other purpose in the problem. The cookie-cutter cells should be defined as simple as possible.

3.2. Creating a Cut-Away view of a 3D Plot using the Visual Editor

Figure 7 shows two cross-sectional views of a pig cask and the cookie-cutter cell (outlined in red) that will be used for the cut-away view. The basis vectors used to make the 2D plot are used to determine the image plane. In this case, we will be plotting against the XY plane on the right to create a cut-away view. In the Visual Editor, new surfaces were defined for the boundary of the cookie-cutter cell to eliminate the possibility that surfaces are already being used for existing cells.
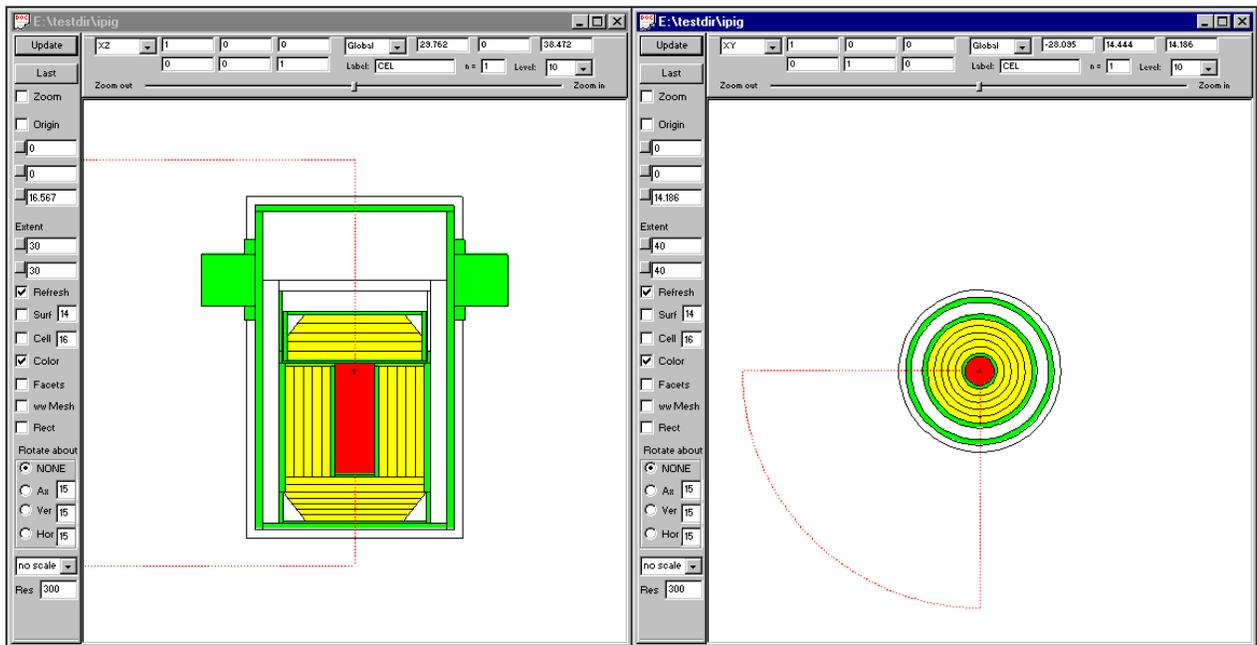

Figure 7 - 2D XZ and XY views for an pig cask

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Figure 8 shows the XY view rotated so that the cut-away section is facing toward the viewpoint. This modifies the basis vector which is used to set up the plot plane for the 3D image. To rotate the figure click in the Ax radio button under "Rotate about" in the XY plot window. The degree angle should read 15. Click update three times to rotate the object 45 degrees. Then click "NONE" so it does not continue to rotate. The black arrow shows the approximate location of the cursor when the screenshot was taken. In the cursor coordinates shown in the three top right boxes, show values that are approximately -20, -20, and 14. For the plot in Figure 7, the viewpoint was set at -40, -40, and 50 to set the viewpoint further away from the object. The Z value was set to 50 to provide a view from above.
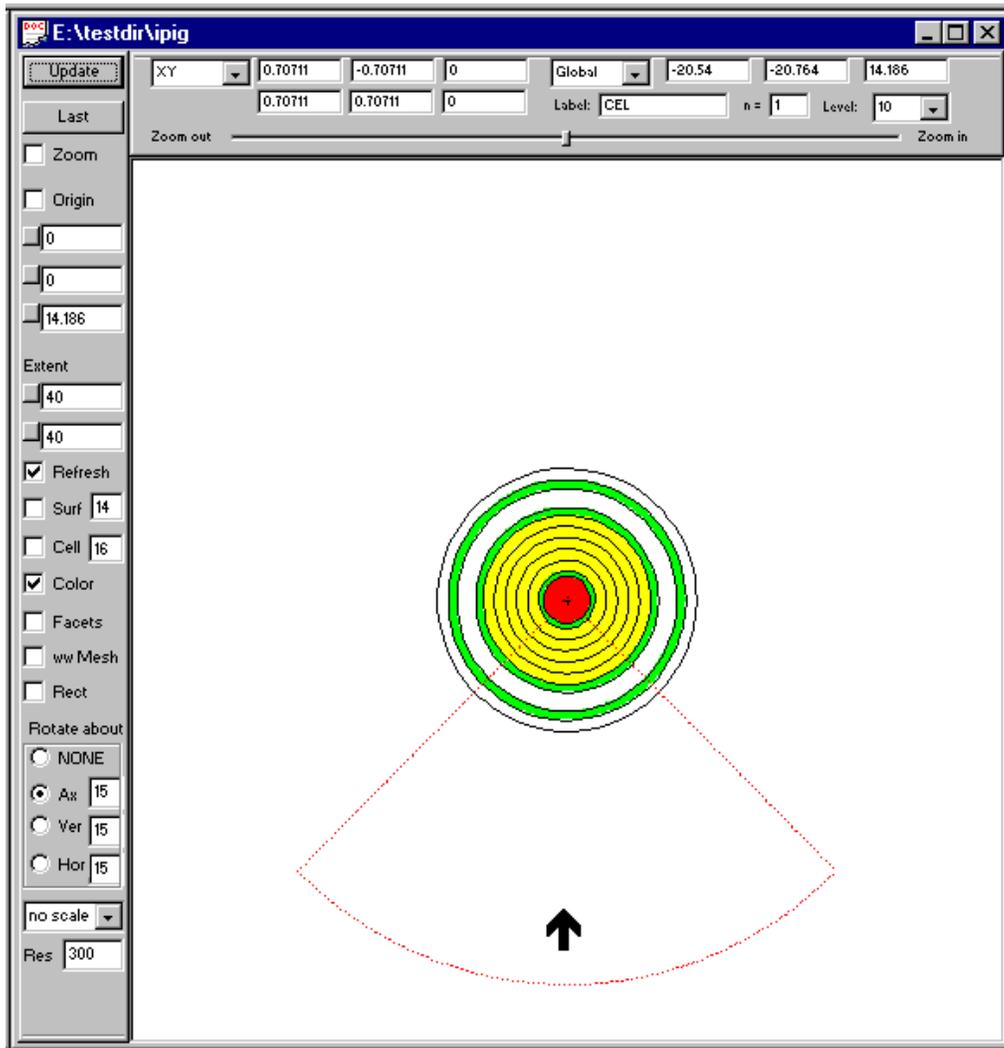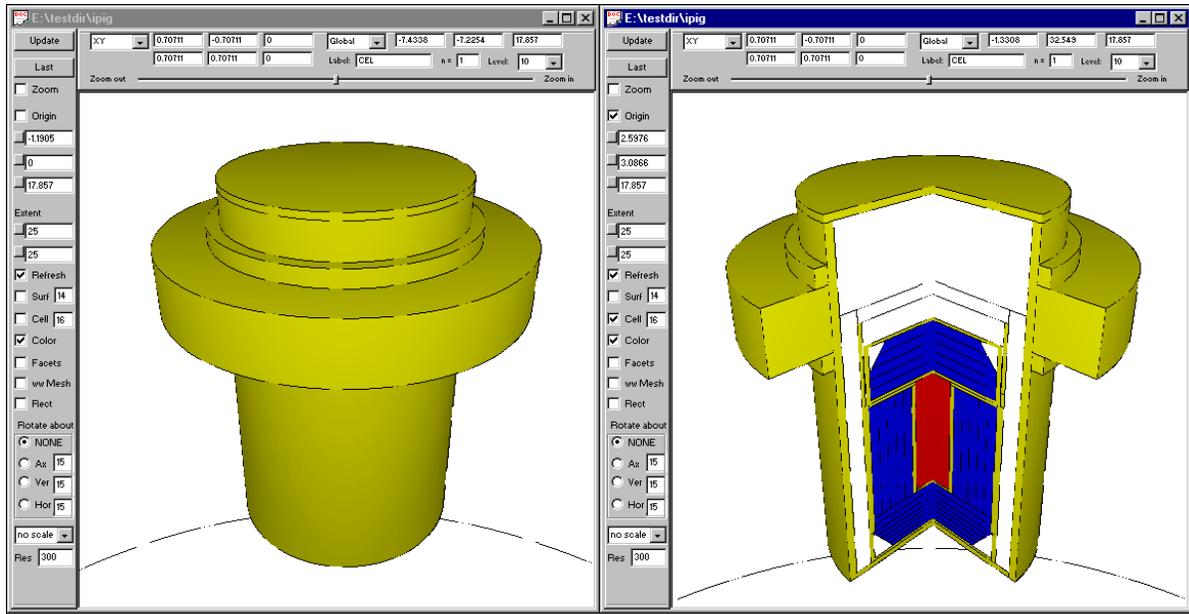

Figure 8 – View Rotated with cursor to set ViewPoint

Figure 9 shows the 3D View of the pig cask on the left and the cut-away view on the right. The plot on the left was made with the "Hide cookie-cutters" option set in the lower middle combo box. This is the default setting.

Figure 9 - 3D View and Cut-Away View of Cask

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4. Radiographic Plotting

4.1. Creating Radiographic Plots

Figure 10 shows a 3D cut-away image and a Radiographic image of a cask containing cesium capsules. The radiographic image is a black and white plot that shows the thickness of the objects in the plot. An option is available to generate a plot where the intensity is represented by the track length multiplied by the cross section for a specific source energy.[3]
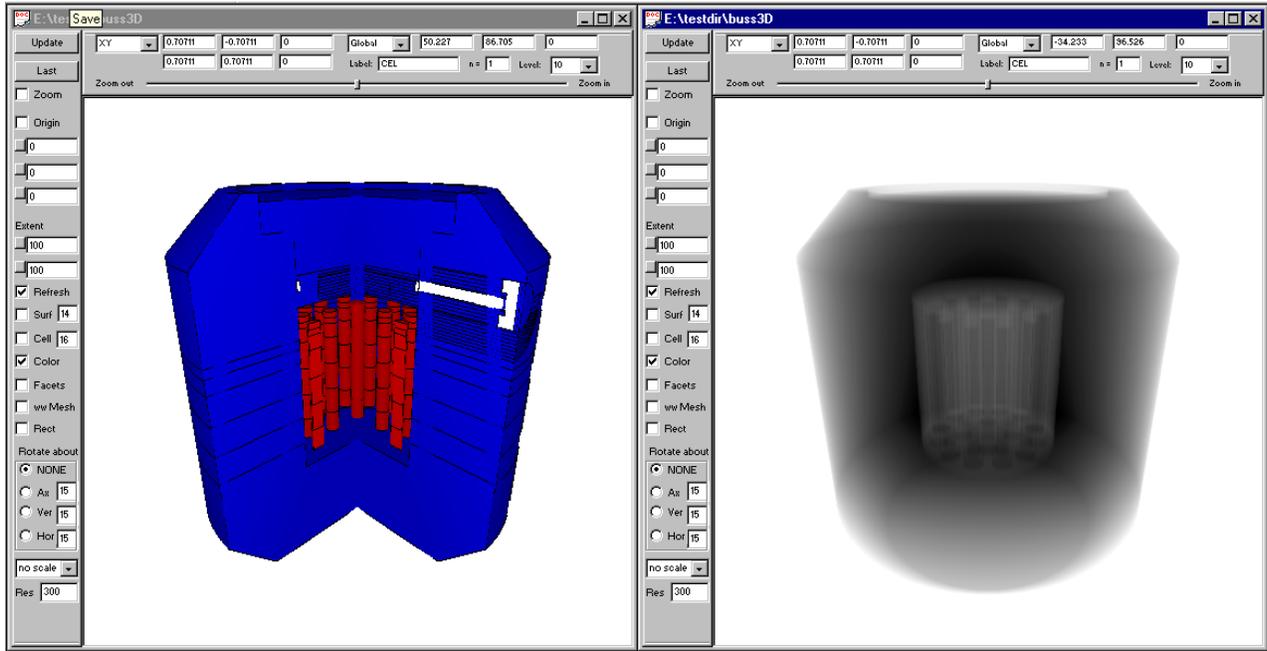

Figure 10 - Radiographic plot of a Cask

4.2. Creating the Radiographic Plot

Figure 11 shows the 3D Plotting menu used to create the plot. Setting up a radiographic plot is very similar to the 3D plotting but requires additional parameters. The "ray length corresponding to pure black (cm)" must be specified. If it is not known at the time of the plotting, select a non-zero value and run an initial trial plot. The maximum radiographic length will be displayed in the output display at the bottom of the window. The last line of the output display in the 3D Plotting menu in Figure 11 shows a maximum radiographic length of approximately 120.
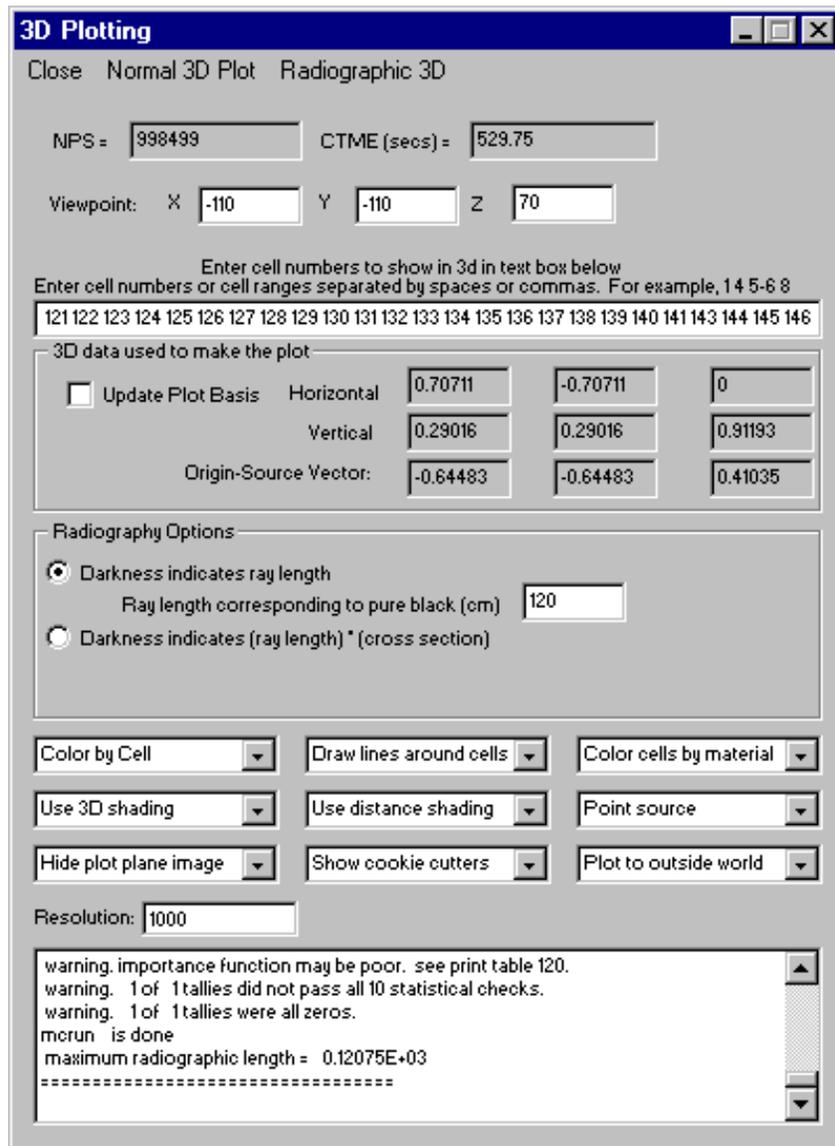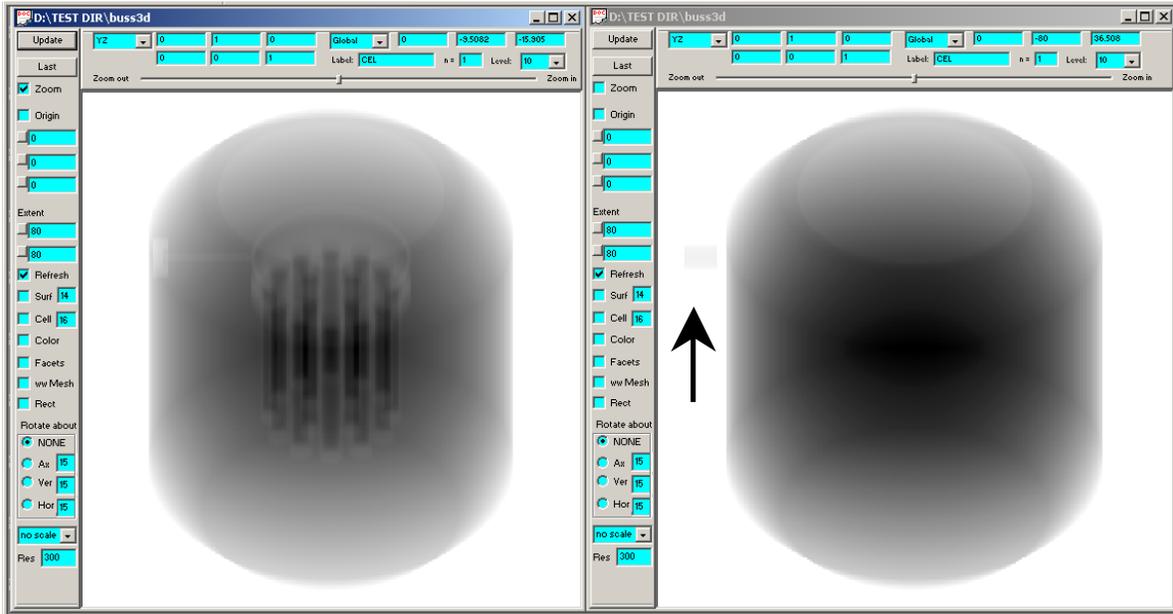

Figure 11 - Menu For Radiographic Plotting of a Cask

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4.3. Radiographic Plot Using a Mono-Energetic Incident Source Energy

Figure 12 - Radiographic Plot for a Fixed Source Energy

Figure 12 shows two different radiographic plots of a cask. In the left plot an incident source energy of 5 MeV is used. In the right plot, the darkness is set equal to the ray path length. By using an incident source energy, it can be multiplied by the cross section for the cells that are passed through to produce an image showing the "density" of the materials that the ray passes through.

In the left plot of Figure 12, the internals of the cask can be seen by using an incident source energy of 5 MeV. Even the port extending out the side of the cask (shown in Figure 10) can be seen. In the right plot, the track length is the same for all materials so it produces a volume plot. The arrow points to a small air cell outside the cask that can be seen floating in the air. This small air cell is not "dense" enough to show up in the left plot.

5. CONCLUSIONS

The addition of 3D plotting in the Visual Editor greatly enhances the users ability to view complex 3D geometries. By using the 2D view to set up the image plane, much of the setup of the 3D image, such as the extents of the view and the plot plane basis vectors, can be done in 2D.

The ability to use the MCNP transport algorithms to generate a 3D plot provides an example of the advantage of creating the graphical interface on top of the MCNP Fortran source code. The radiographic imaging capability also takes advantage of the MCNP data readily available to the Visual Editor.

Current information on Visual Editor features, recent developments, and training classes can be found at www.mcnpvised.com.

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