

## **ANIMATION OF MCNP PARTICLE TRACKS IN MORITZ**

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### **ABSTRACT**

We describe a new animation feature implemented in Moritz that shows MCNP Monte Carlo particles moving in time. The data is taken from the particle track (PTRAC) file. The particles are shown together with the geometry in a dynamic 3D display that can be interactively rotated, scaled, and panned. The particle time is interpolated between the event times in the particle track file. The particles are shown as points or 3D symbols. The animation can show only the particles or also include all or a segment of the track behind the particles. The track in the segment option represents a selectable time interval. The user has control over the display interval and model time between frames. The particle and track color may be based on energy, weight, or time. Moritz's inclusion and exclusion filters determine which histories and/or branches of histories are shown in the animation. Two other animations are available. History animation shows the track of each history for a specified interval. Kcycle animation sequences through the particles tracks from a KCODE criticality calculation by cycle number. It is useful for verifying that source points are distributed uniformly in the fissile material. The current value of each animation—time, history number, or cycle number—is shown in the program window.

*Key Words:* Moritz, MCNP, MCNPX, Particle Tracks, Animation

### **1 INTRODUCTION**

The visualization of microscopic phenomena in a Monte Carlo simulation can improve the understanding of the problem and provide an important check on model definition and execution. The paths, or tracks, of Monte Carlo particles show how these particles move through the model and give insight on the both the predominant transport routes and rare but important events. Examination of paths to a selected detector cell shows the important regions of a model and can suggest strategies for variance reduction. Plots of source points and initial tracks are used to verify and debug source definitions. Color coding of the tracks by energy, weight, or time gives a quick indication of how these quantities vary throughout the model.

The MCNP [1] and MCNPX [2] Monte Carlo transport codes can write a file of particle track information (“PTRAC” file) containing the position, energy, time, and other information of a particle at creation, interactions, surface crossings, and terminations. Various filters can restrict which histories are written, such as including only those that enter a cell or contribute to a tally. Several programs, including the Visual Editor [3], Sabrina [4, 5, 6], and Moritz [7], display some or all of the tracks according to criteria set by the user.

As the number of histories shown increases, the particle track plot becomes crowded and the paths of individual particles are difficult to discern (such as in Fig. 1). To reduce crowding, one can calculate only a small number of histories with the Monte Carlo code or set limits in the display program. A sparse set of histories, however, may not contain tracks with an interesting

path, such as penetration through thick obstacles. Running another Monte Carlo calculation with a different set of histories is tedious; changing the display limits is less so but still inconvenient. Useful plots can often be produced by the application of filters that include only histories that meet some criteria (e.g. crossing some surface) or excluding certain histories. A history may include a number of secondary particles created by interactions and variance reduction features; the tracks of these additional particles are known as *branches*. Filters can be applied to entire histories or branch by branch. Bounding limits the portion of the track plotted to be between specified limits in Cartesian coordinates, energy, weight, and/or time.

We have implemented new particle track display modes in Moritz that offer meaningful visualization while using a relatively large number of histories. Time animation shows points representing the particles moving in time. The animation can show only particle markers or can include all or a portion of the tracks behind the particle markers. The animation will help the expert in both understanding the dynamics of the model and explaining the transport behavior to a layperson. History animation consists of displaying each history for a brief time, allowing for comparison of various histories and selection of interesting histories for more detailed study. In Kcycle animation, the tracks from each successive cycle of a criticality calculation are shown for a set interval. By plotting only the source points, one can see how the neutrons migrate from cycle to cycle and verify (or not) that the source points give adequate coverage of the fissile material by the end of the inactive cycles.

All three animations display the particle tracks in the three dimensional (3D) display. While an animation is underway, the user can manipulate the display by rotating, zooming, and panning and change options affecting the tracks, such as the color coding. Any filters and bounds that were set remain in effect during the animation and can be changed during the animations.



**Figure 1. Particle tracks from a skyshine calculation**

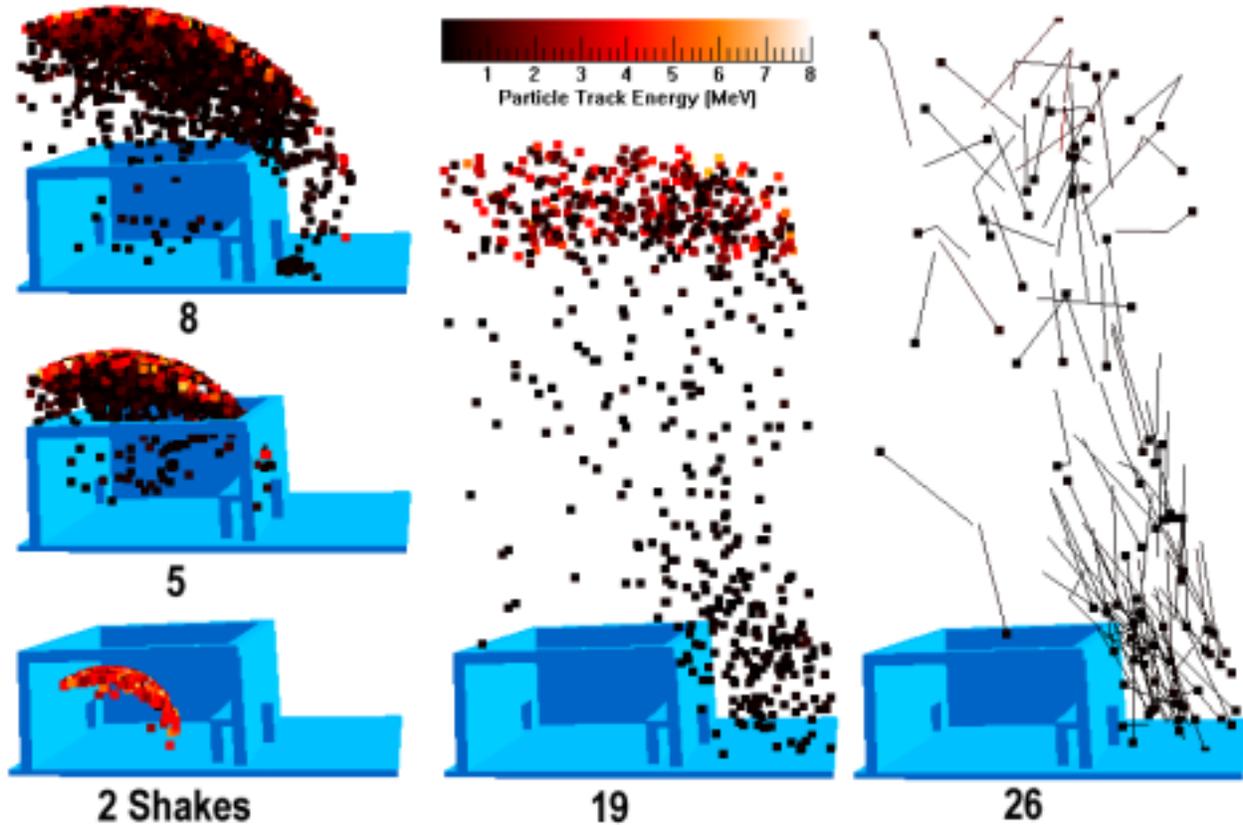


Figure 2. Frames from the time animation of Fig. 1 with times given in shakes ( $10^{-8}$  second)

## 2 TIME ANIMATION

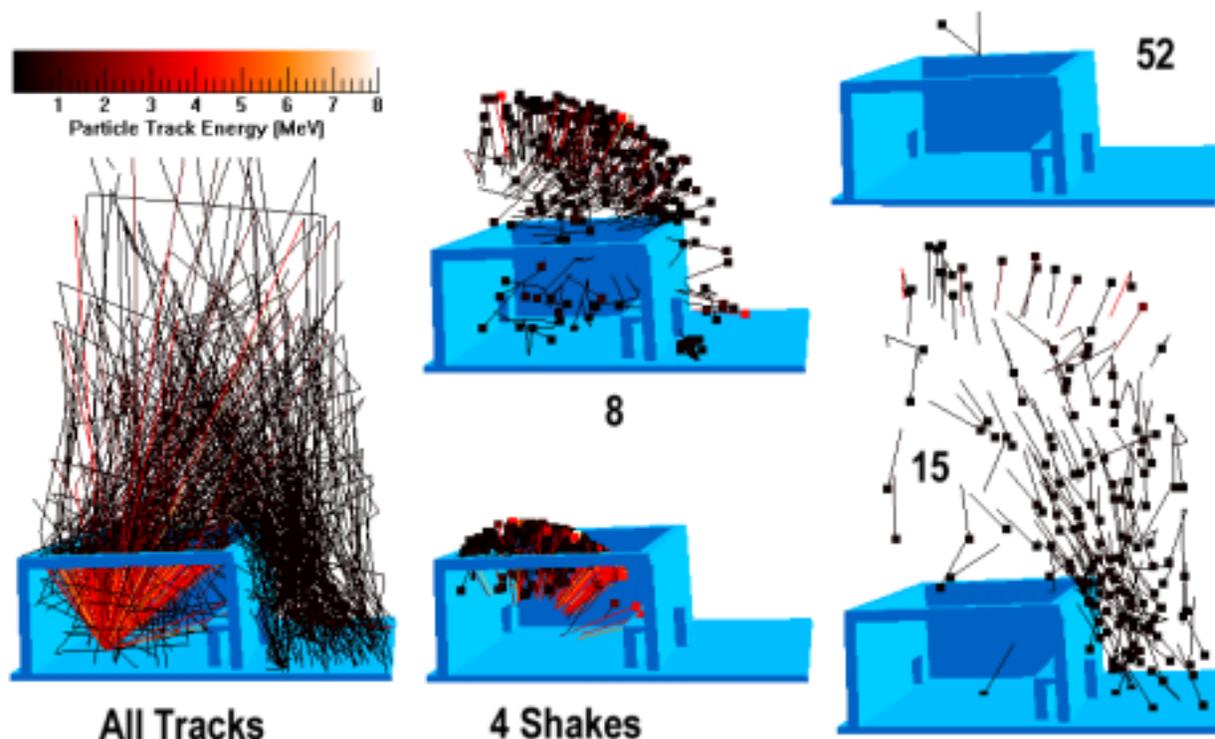
The particle track data consists of a sequence of events. Among the information associated with each event is the position (X, Y, & Z) and time (if the MCNP/MCNPX PTRAC command includes the WRITE = ALL keyword). Particle track paths are constructed of straight line segments between successive event positions.

### 2.1 Animation Times

The position of a particle at a given time  $t$  is found by linear interpolation along the line connecting the two events whose times bracket  $t$ . In the time animation,  $t$  is continuously incremented or decremented by the time step  $dt$  and the particles are displayed at the new time. Each frame is displayed for a user specified interval, typically a fraction of a second. The animation may run more slowly than the requested interval if a large number of tracks and/or graphics elements shown require more time to process and display.

The user can give an explicit value for  $dt$  or specify the number of time steps  $N$ , in which case

$$dt = (T_0 - T_N) / N \quad (1)$$



**Figure 3.** Tracks of Fig. 1 excluding branches terminated by escape (left) and frames from a time animation

where  $T_0$  and  $T_N$  are the time limits of the animation. These limits can be set to the extremes of the times in the track data or set by the user. A user value for  $T_N$  is advantageous in models where a few particles are present for a long time while not doing much, such as some low energy neutrons rattling around before termination. The animation may be a single sequence between  $T_0$  and  $T_N$  (or in reverse from  $T_N$  to  $T_0$ ), or it can loop continuously. When looping, the movement can always be in the same direction in time, or the direction can change at each limit—changing from forward to reverse when  $T_N$  is reached and from reverse to forward at  $T_0$ .

## 2.2 Display Style

The particle position is shown as a point or a 3D marker. A point is a small square drawn at the projected position on the screen. The marker can be a pyramid, cube, or sphere. The point size is specified in pixels, while the marker size is either an absolute value in model units or a fraction of the model extent. The color is derived from the coloring scheme used for the tracks. All or some of the particle track behind the point or marker may be shown. In the partial track case, the track length represents a user specified time interval. When the animation direction is reverse in time, the tracks or partial tracks are for times greater than the particle position.

Increasing the complexity of the position marker and adding trailing tracks increases the number of graphics elements that must be processed and displayed, possibly resulting in frame intervals displaying more slowly than requested. Which combination of the number of histories and display complexity results in degraded performance depends on the capacity of the computer. When increased complexity is desired, such as trailing tracks, it may be desirable to decrease the number of histories plotted by the application of filters or bounds.

The user may set a number of histories to be displayed during the animation rather than all histories available. For continuously running animations, the starting history of the set shown advances to the next history present when the animation starts again from  $T_0$ .

### 2.3 Skyshine Example

Fig. 1 shows tracks of photons from a skyshine calculation. The ceiling and front wall of the radiography room (blue) are transparent in the figures. The photons are emitted in an upwards conical direction from a point near the floor. A PTRAC filter in MCNP was used to select histories that crossed a surface to the right of the room. The tracks are colored by energy from 0 MeV (black) to 8 MeV (orange). The energy legend is shown in Fig. 2. That figure shows several frames from the animation of the tracks in Fig. 1. The particle positions are shown as points.

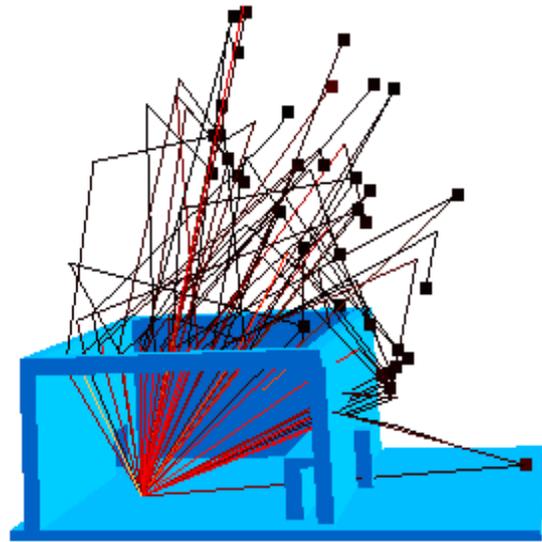


Figure 4. Frame from a time animation at 11 shakes with trailing particle tracks

The frames are labeled by the time in shakes ( $10^{-8}$  second). At 2 shakes, the spherical front of energetic photons is within the room. At 5 shakes, the front has passed through the ceiling where scatterings have decreased the average energy in the front and resulted in downward directed low energy photons. Several photons have penetrated the right wall. As the front continues to move upward (8 and 19 shakes), scatterings in the air result in downward moving low energy photons. By 26 shakes, the front has moved out of the modeled space. Trailing track segments show the direction of the photons; changes in the track directions indicate scatterings.

In Fig. 3, a filter is used to exclude branches that terminate by escape. The left panel shows the tracks with the exclusion filter applied. The other panels are frames from the animation with trailing track segments. Two segments at the top of the 15 shakes frame exhibit down scattering in both direction and energy. The 52 shakes frame shows a photon scattering off of the roof.

Fig. 4 is frame from an animation with trailing tracks. The set of tracks visible was reduced by pruning the tracks to an air cell to the right of the room. Pruning selects the branches in a history that lead to a specified cell or surface. The branches that do not contribute to the path and the histories that do not encounter the cell or surface are not shown.

## 3 HISTORY ANIMATION

History animation displays a single history for a specified interval. The mode can run through all histories once or continuously loop through them. Fig. 5 shows 2 histories from the skyshine example.

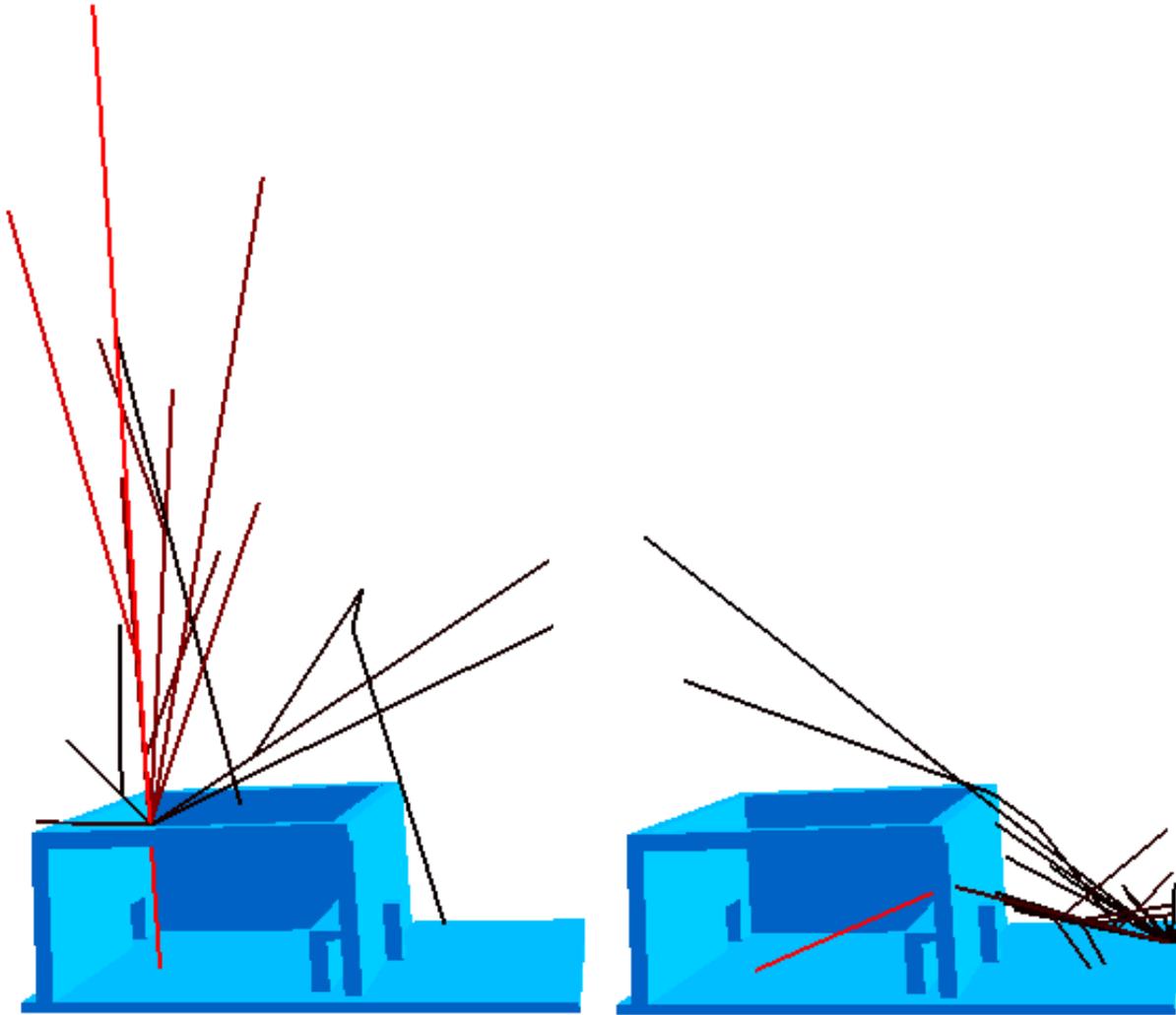


Figure 5. Two frames from a history animation of the tracks shown in Fig. 1

#### 4 KCYCLE ANIMATION

Kcycle animation shows the tracks from a single criticality calculation cycle, advancing to the next cycle after the display interval. It can run through all cycles once or loop. In a criticality calculation, the fission neutrons produced in one cycle become the sources for the next cycle. For an accurate result, neutrons should evenly sample all of the fissile material; that result is achieved when the source points for a cycle show uniform coverage. A Kcycle animation of the source points shows how the neutrons move through the model and how quickly the model is (or is not) moving to uniform coverage. Fig. 6 shows five frames from a Kcycle animation of a 2 tank aqueous uranyl nitrate solution criticality model. Adequate coverage has been reached by cycle 12.

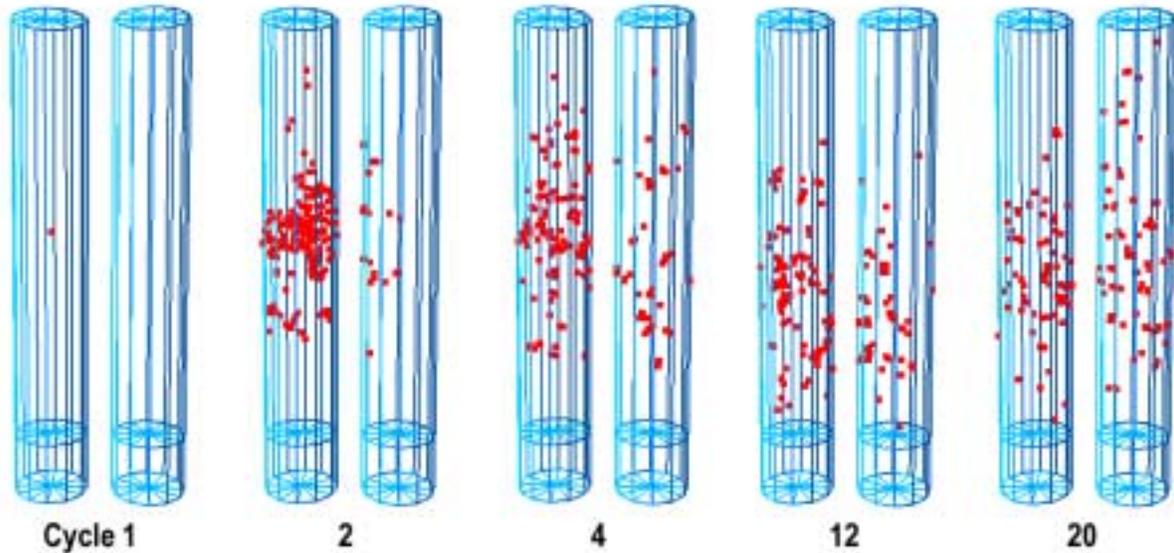


Figure 6. Frames from a Kcycle animation of 2 tank uranium solution criticality problem

## 5 USER CONTROL

Parameters controlling the animations are set on dialogs. From these dialogs, one can enter one of the animation modes or a corresponding manual mode. In the manual modes, time, history, or cycle is incremented or decremented using the arrow keys. When an animation is active, pressing an arrow key stops the animation and enters the manual mode. When either the animation or manual mode is terminated, all tracks (subject to any filters and bounds in effect) are displayed. The modes are terminated from the respective dialog or by a function key. Function keys can also be used to start the animations. During an animation or manual mode, the status bar at the bottom of the Moritz program window shows the time, history, or cycle number of the current frame.

Moritz can save the pictures as a bitmap file. During an animation, each frame can be saved as a bitmap so that the set of files can then be collected into a movie file by a program such as Microsoft's Windows Movie Maker.

## 6 SUMMARY

We have implemented several animated particle track display features in the Moritz code. The time, history, and Kcycle animations and corresponding manual modes complement the existing set of track filters and bounds for analysis of transport calculations by visualization of the particle tracks. Time animation shows the dynamics of a model. It should be a suitable tool for evaluating transport behavior and explaining it to nonprofessionals.

## 7 REFERENCES

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