RadSim

A program to simulate particle interactions in matter

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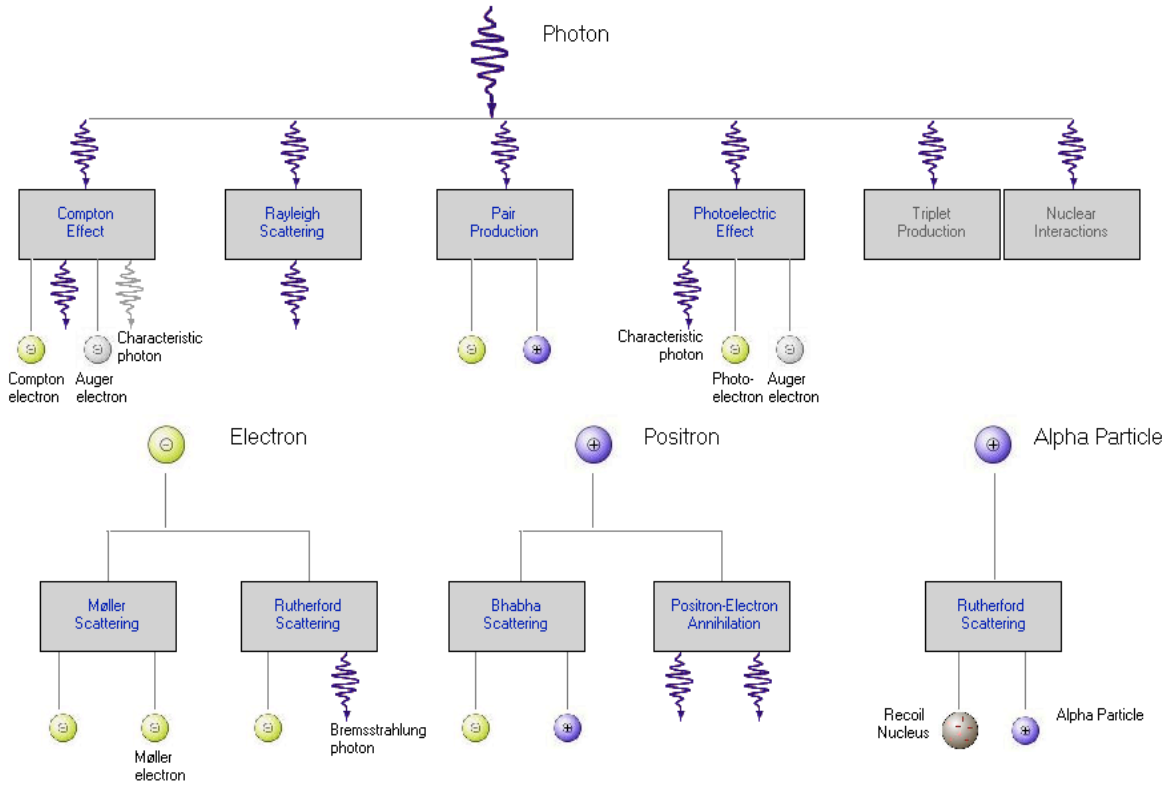
INTRODUCTION

RadSim is an interactive program that gives students a chance to learn about different radiation processes through user-defined simulations, graphs and animations. Each interaction window has a *manual mode* and *simulated mode*. In the *manual mode*, the user chooses a number of conditions for a single event, and the program calculates the resulting data. The *simulated mode* is designed to be more representative of a real-world situation, whereby the user chooses the initial conditions, and the resulting data is calculated according to the laws of probability.

Opening Window

Click Start to see the Selection Window or choose an interaction from the Simulation Menu to go directly to it.

Selection Window

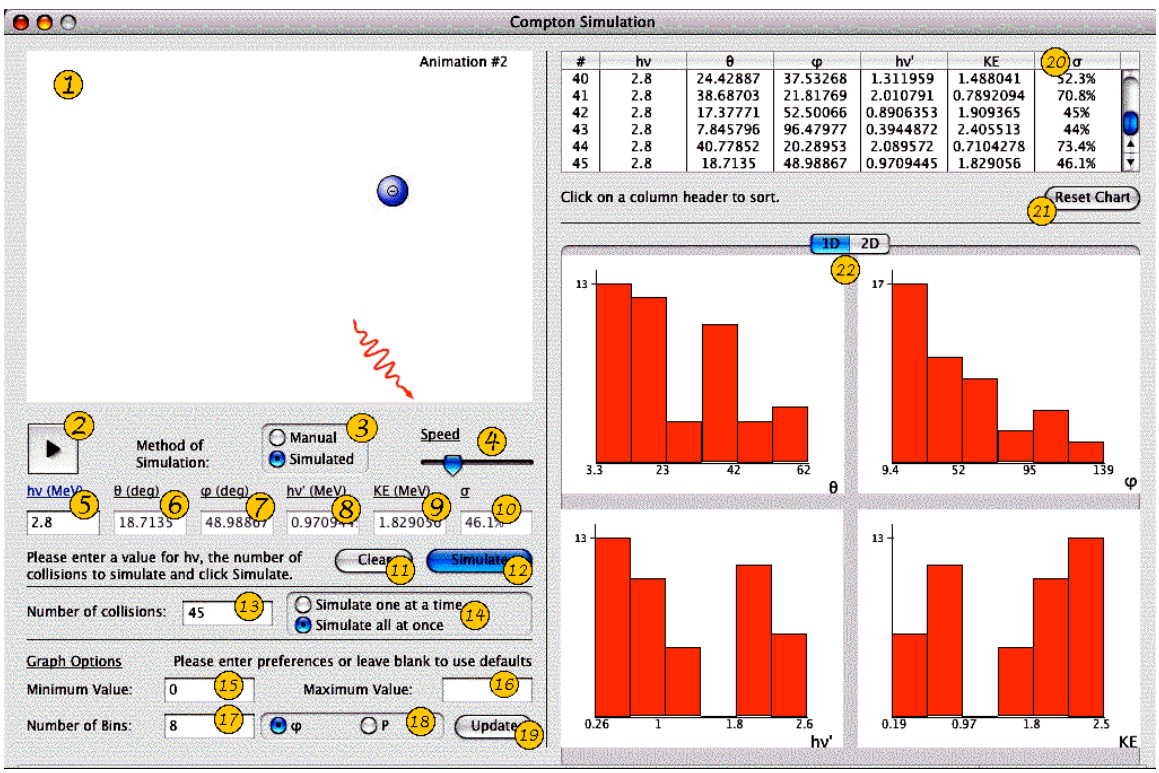


Click on one of the interactions to go to it. Triplet Production and Nuclear Interactions have not been modeled.

INTERACTIONS MODELLED

Compton Interaction

Compton Effect (Klein-Nishina approach) describes the interaction between a stationary electron and an incoming photon. After the collision, the two particles depart in different directions. It takes into account six variables: the initial photon quantum energy $h\nu$, the angle at which the electron departs θ, the angle at which the photon is scattered φ, the final photon quantum energy $h\nu'$, the electron kinetic energy K, and the relative probability of this event happening σ, normalized to a maximum 100%. In manual mode, the user enters any two variables (except σ) and the other four values are calculated. In simulated mode, the user enters only $h\nu$ and the number of collisions to model, and the results are collected in a table and a series of one- and two-dimensional histograms.



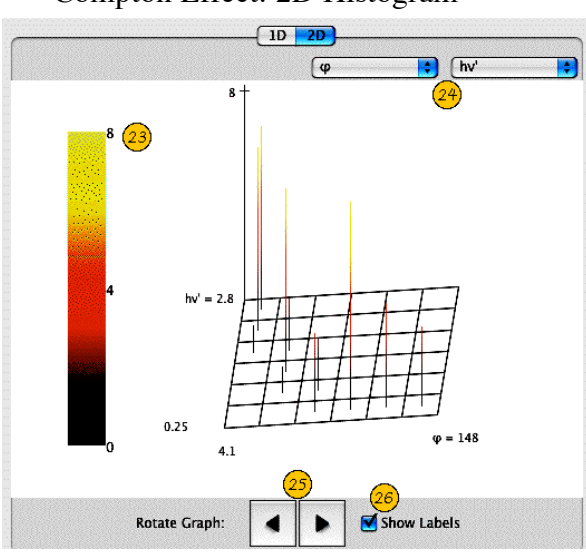
1. The animation window shows what happens when the particles interact.
2. This button starts and pauses the animation.
3. The manual and simulated radio buttons switch between manual and simulated mode.
4. The Speed slider controls the speed of the animation, as well as the speed of the simulation if you have chosen to simulate the events one at a time.
5. In manual mode, you may enter $h\nu$ in this box; in simulated mode, you must enter $h\nu$ in this box.
6. In manual mode, you may enter θ in this box; in simulated mode, θ is displayed in this box.

7. In manual mode, you may enter φ in this box; in simulated mode, φ is displayed in this box.
8. In manual mode, you may enter $h\nu'$ in this box; in simulated mode, $h\nu'$ is displayed in this box.
9. In manual mode, you may enter K in this box; in simulated mode, K is displayed in this box.
10. This box displays σ.

Note: In manual mode, enter any two values other than σ, and the other four quantities are calculated automatically. In simulated mode, enter values for $h\nu$ and the number of interactions to simulate, then click Simulate to begin the calculations.

11. The Clear button clears the five input text boxes (numbers 5-10).
12. In simulated mode, the Simulate button begins the simulation based on the data entered (numbers 5-10), shows the results in the table and graph, and starts the animation. In manual mode, this becomes the Add to Chart button, and it adds the data from the five input text boxes (numbers 5-10) to the table.
13. In this box, enter the number of interactions to simulate.
14. Use these radio buttons to choose if the program simulates the events one at a time or all at once.
15. In this box, enter the desired lower boundary of the graph.
16. In this box, enter the desired upper boundary of the graph.
17. In this box, enter the desired number of bins of the graph.
18. These radio buttons let you choose which variable to update.
19. The Update button refreshes the graph with the new parameters (numbers 15-18).
20. The table tracks each result, and can be sorted according to any variable by clicking on the column header. To re-order the rows manually, click and drag a row to move it.
21. This button resets the chart and graphs.
22. The graph window shows the results through customizable one- or two-dimensional graphs. Toggle between 1D and 2D using the tabs at the top of the graph window. See below for 2D instructions.

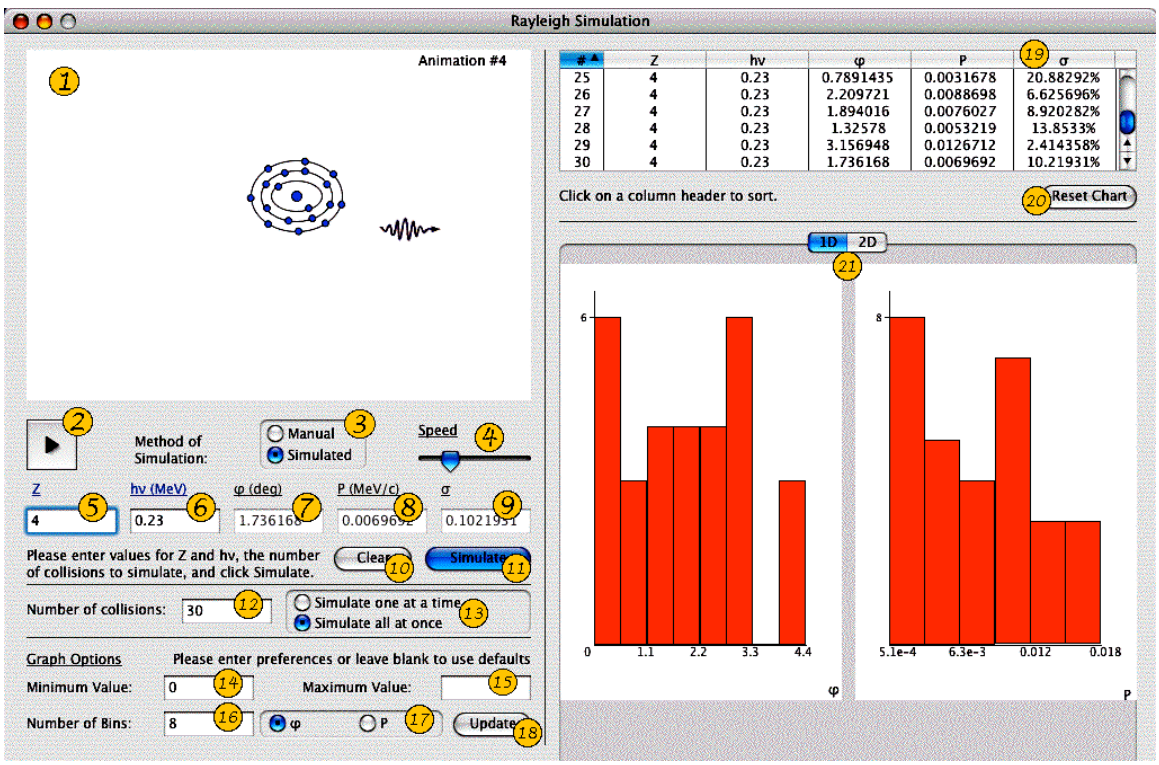
Compton Effect: 2D Histogram



23. This legend shows how the height of a bar is related to its frequency.
24. Use these popup menus to choose the variables of the graph.
25. These buttons rotate the graph clockwise and counter-clockwise.
26. This checkbox turns the labels on and off.

Rayleigh Interaction

Rayleigh (Coherent) Scattering describes the interaction between a stationary atom and an incoming photon. After the collision, the photon is scattered, and the atom recoils only slightly. It takes into account five variables: the atomic number of the atom Z, the initial photon quantum energy $h\nu$ (which essentially does not change after the collision), the angle at which the photon is scattered φ, the recoil momentum of the atom P, and the relative probability of this event happening σ. In manual mode, the user enters Z, $h\nu$ and either φ or P, and the remaining data are calculated. In simulated mode, the user enters only Z and $h\nu$, and the results are collected in a table, two one-dimensional histograms and a single two-dimensional histogram.

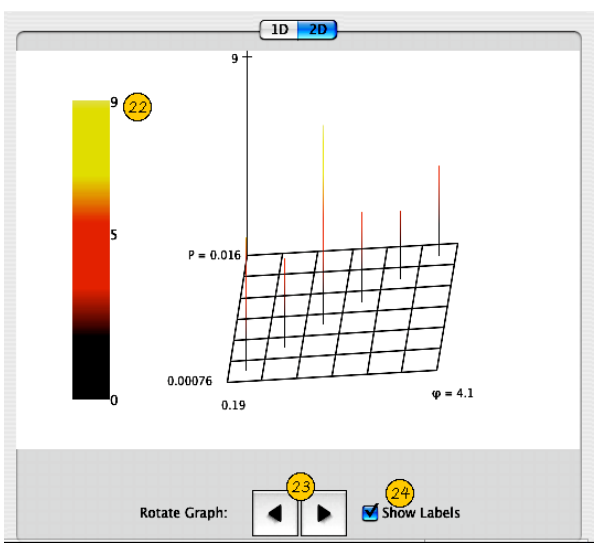


1. The animation window shows what happens when the particles interact.
2. This button starts and pauses the animation.
3. The Manual and Simulated radio buttons switch between manual and simulated mode.
4. The Speed slider controls the speed of the animation, as well as the speed of the simulation if you have chosen to simulate the events one at a time.
5. In this box, enter Z.
6. In this box, enter $h\nu$.
7. In manual mode, you may enter φ in this box; in simulated mode, φ is displayed in this box.
8. In manual mode, you may enter P in this box; in simulated mode, P is displayed in this box.
9. This box displays σ.

Note: In manual mode, enter a value for Z, $h\nu$, and either φ or P, and the other two quantities are calculated automatically. In simulated mode, enter values for Z, $h\nu$, and the number of interactions to simulate, then click Simulate to begin the calculations.

10. The Clear button clears the five input text boxes (numbers 5-9).
11. In simulated mode, the Simulate button begins the simulation based on the data entered (numbers 5-9), shows the results in the table and graph, and starts the animation. In manual mode, this becomes the Add to Chart button, and it adds the data from the five input text boxes (numbers 5-9) to the table.
12. In this box, enter the number of interactions to simulate.
13. Use these radio buttons to choose if the program simulates the events one at a time or all at once.
14. In this box, enter the desired lower boundary of the graph.
15. In this box, enter the desired upper boundary of the graph.
16. In this box, enter the desired number of bins of the graph.
17. These radio buttons let you choose which variable to update.
18. The Update button refreshes the graph with the new parameters (numbers 14-17).
19. The table tracks each result, and can be sorted according to any variable by clicking on the column header. To re-order the rows manually, click and drag a row to move it.
20. This button resets the chart and graphs.
21. The graph window shows the results through customizable one- or two-dimensional graphs. Toggle between 1D and 2D using the tabs at the top of the graph window. See below for 2D instructions.

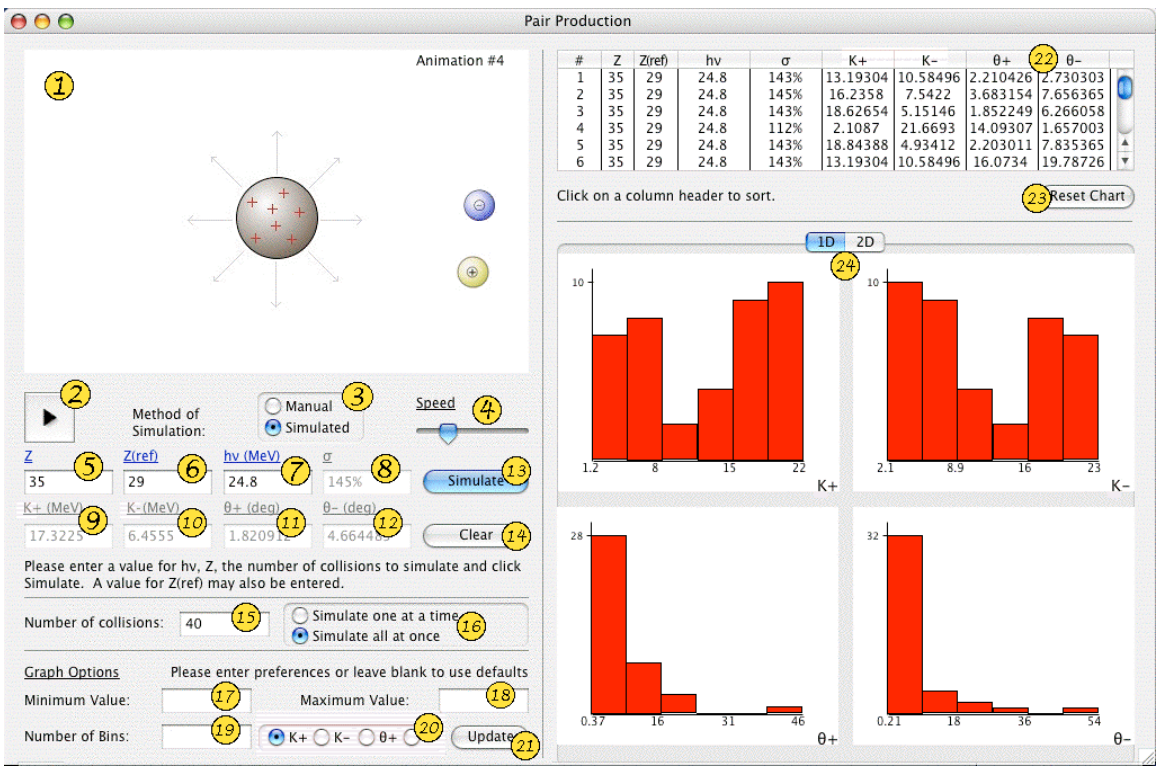
Rayleigh Interaction: 2D Histogram



22. This legend shows how the height of a bar is related to its frequency.
23. These buttons rotate the graph clockwise and counter-clockwise.
24. This checkbox turns the labels on and off.

Pair Production

Pair Production describes the interaction between a stationary nucleus and an incoming photon. When the photon enters the nucleus' Coulomb force field, it is absorbed, and gives rise to an electron and a positron. It takes into account eight variables: the atomic number of the atom *Z*, the atomic number of the reference atom *Z(ref)*, the initial photon quantum energy $h\nu$, the kinetic energy of the positron *K*+, the kinetic energy of the electron *K*-, the angle of departure of the positron θ+, the angle of departure of the electron θ-, and the relative probability of this event happening σ. In manual mode, the user enters *Z*, $h\nu$, either *K*+ or *K*-, and, if a reference atom is desired, *Z(ref)*. The remaining data are then calculated. In simulated mode, the user enters only *Z*, $h\nu$, and, if a reference atom is desired, *Z(ref)*, and the results are collected in a table, four one-dimensional histograms and two two-dimensional histograms.



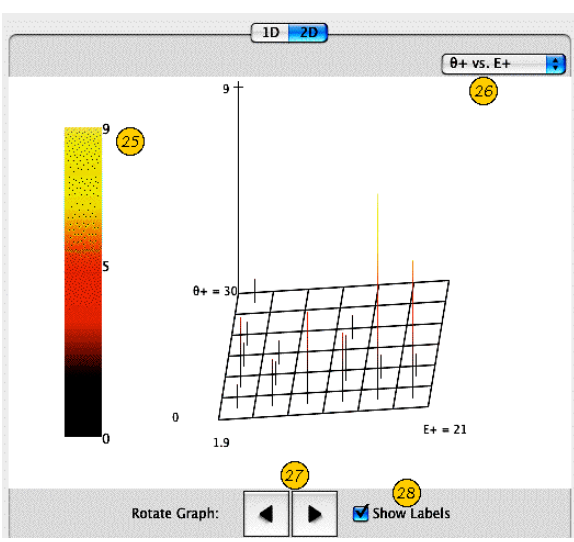
1. The animation window shows what happens when the particles interact.
2. This button starts and pauses the animation.
3. The manual and simulated radio buttons switch between manual and simulated mode.
4. The Speed slider controls the speed of the animation, as well as the speed of the simulation if you have chosen to simulate the events one at a time.
5. In this box, enter *Z*.
6. If you want to have a reference atom, enter *Z(ref)* in this box.
7. In this box, enter $h\nu$.
8. This box displays σ.

9. In manual mode, you may enter *K*+ in this box; in simulated mode, *K*+ is displayed in this box.
10. In manual mode, you may enter *K*- in this box; in simulated mode, *K*- is displayed in this box.
11. This box displays θ+.
12. This box displays θ-.

Note: In manual mode, enter values for *Z*, $h\nu$, either *K*+ or *K*-, and, if you want to have a reference atom, *Z(ref)*. The other five quantities will then be calculated automatically. In simulated mode, enter values for Z, hν, if you want to have a reference atom, *Z(ref)*, and the number of interactions to simulate, then click Simulate to begin the calculations.

13. In simulated mode, the Simulate button begins the simulation based on the data entered (numbers 5-12), shows the results in the table and graph, and starts the animation. In manual mode, this becomes the Add to Chart button, and it adds the data from the eight input text boxes (numbers 5-12) to the table.
14. The Clear button clears the eight input text boxes (numbers 5-12).
15. In this box, enter the number of interactions to simulate.
16. Use these radio buttons to choose if the program simulates the events one at a time or all at once.
17. In this box, enter the desired lower boundary of the graph.
18. In this box, enter the desired upper boundary of the graph.
19. In this box, enter the desired number of bins of the graph.
20. These radio buttons let you choose which variable to update.
21. The Update button refreshes the graph with the new parameters (numbers 17-20).
22. The table tracks each result, and can be sorted according to any variable by clicking on the column header. To re-order the rows manually, click and drag a row to move it.
23. This button resets the chart and graphs.
24. The graph window shows the results through customizable one- or two-dimensional graphs. Toggle between 1D and 2D using the tabs at the top of the graph window. See below for 2D instructions.

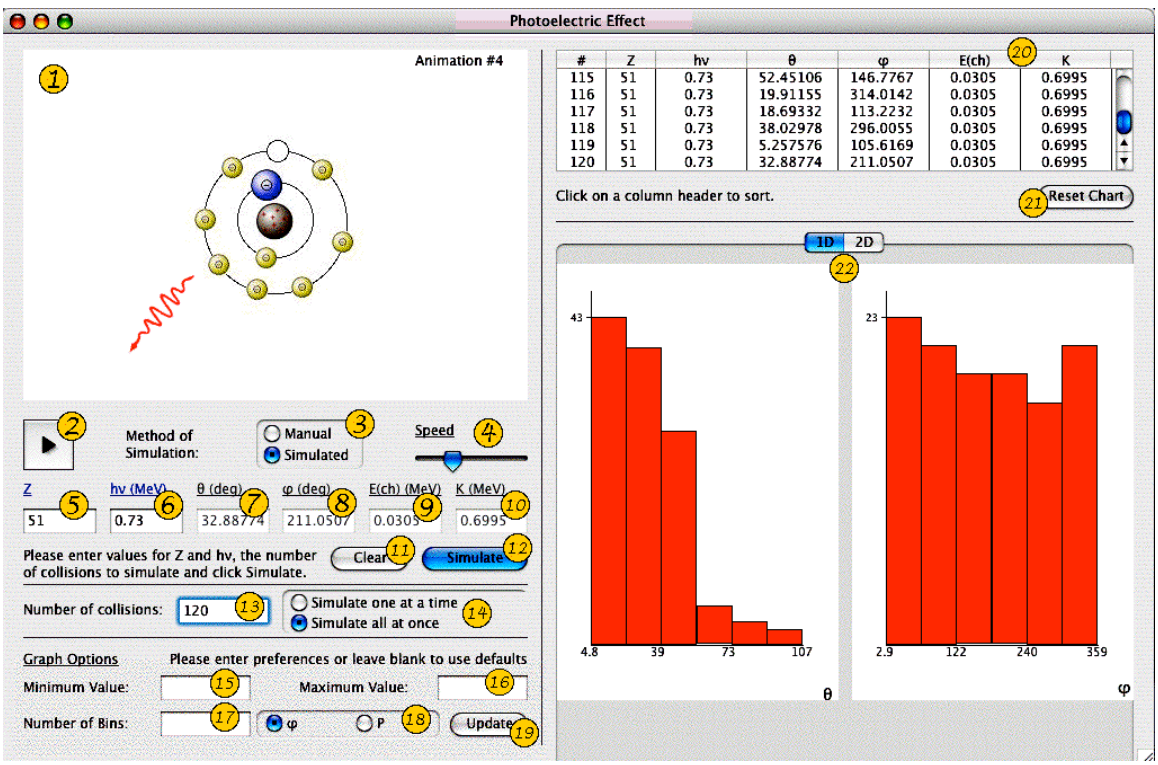
Pair Production: 2D Histogram



25. This legend shows how the height of a bar is related to its frequency.
26. Choose the graph with this popup menu.
27. These buttons rotate the graph clockwise and counter-clockwise.
28. This checkbox turns the labels on and off.

Photoelectric Interaction

Photoelectric Interaction describes the interaction between a stationary atom and an incoming photon. The photon is absorbed by the atom, and a K-shell electron is ejected. An L-shell electron takes its place, and, if the atom has an atomic number of at least 9, a characteristic photon is emitted. It takes into account six variables: the atomic number of the atom Z, the initial photon quantum energy $h\nu$, the angle at which the electron departs θ, the angle at which the photon is emitted φ, the energy of the characteristic photon $E(ch)$, and the electron kinetic energy K. In manual mode, the user enters values for Z and $h\nu$ and the other four values are calculated. In simulated mode, the user enters values for Z and $h\nu$ and the number of collisions to model, and the results are collected in a table and a series of one- and two-dimensional histograms.



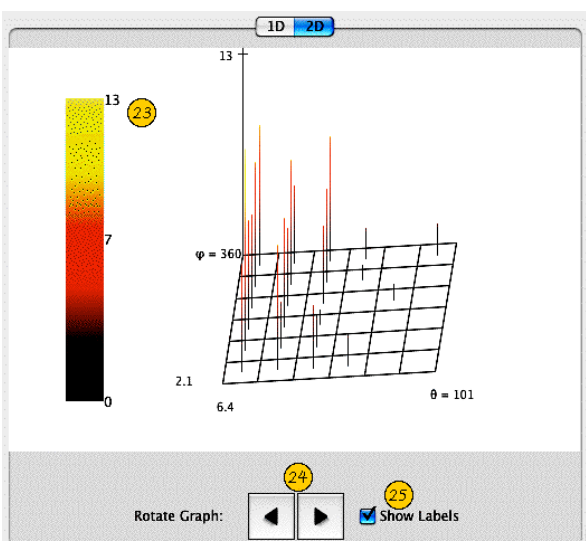
1. The animation window shows what happens when the particles interact.
2. This button starts and pauses the animation.
3. The manual and simulated radio buttons switch between manual and simulated mode.
4. The Speed slider controls the speed of the animation, as well as the speed of the simulation if you have chosen to simulate the events one at a time.
5. In this box, enter Z.
6. In this box, enter $h\nu$.
7. This box displays θ.
8. This box displays φ.
9. This box displays $E(ch)$.

10. This box displays *K*.

Note: Enter values for *Z* and h*ν*. In manual mode, the other values will be calculated automatically. In simulated mode, also enter the number of interactions to simulate, then click the Simulate button to begin the calculations.

11. The Clear button clears the six input text boxes (numbers 5-10).
12. In simulated mode, the Simulate button begins the simulation based on the data entered (numbers 5-10), shows the results in the table and graph, and starts the animation. In manual mode, this becomes the Add to Chart button, and it adds the data from the five input text boxes (numbers 5-10) to the table.
13. In this box, enter the number of interactions to simulate.
14. Use these radio buttons to choose if the program simulates the events one at a time or all at once.
15. In this box, enter the desired lower boundary of the graph.
16. In this box, enter the desired upper boundary of the graph.
17. In this box, enter the desired number of bins of the graph.
18. These radio buttons let you choose which variable to update.
19. The Update button refreshes the graph with the new parameters (numbers 15-18).
20. The table tracks each result, and can be sorted according to any variable by clicking on the column header. To re-order the rows manually, click and drag a row to move it.
21. This button resets the chart and graphs.
22. The graph window shows the results through customizable one- or two-dimensional graphs. Toggle between 1D and 2D using the tabs at the top of the graph window. See below for 2D instructions.

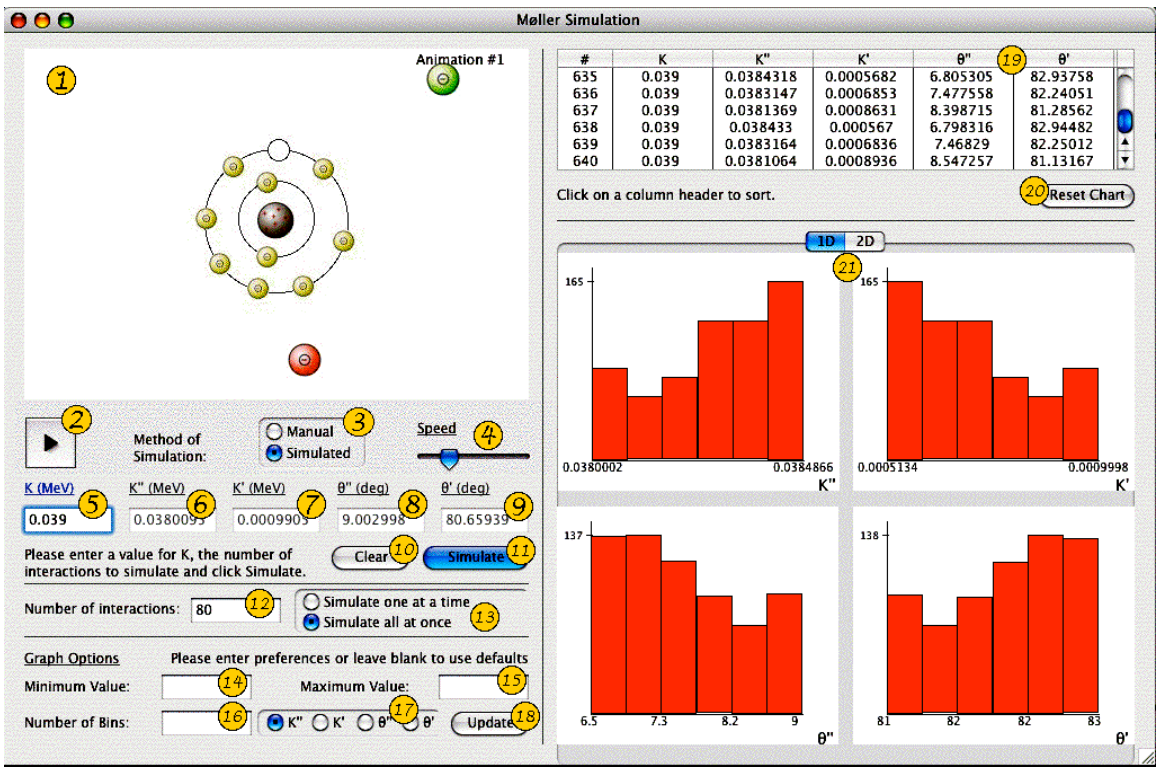
Photoelectric Interaction: 2D Histogram



23. This legend shows how the height of a bar is related to its frequency.
24. These buttons rotate the graph clockwise and counter-clockwise.
25. This checkbox turns the labels on and off.

Møller Inelastic Scattering

Møller Scattering describes the interaction between the orbital electrons of a stationary atom and an incoming electron. The electron knocks one of the orbiting electrons out of its shell. It takes into account five variables: the kinetic energy of the incoming electron before the interaction *K*, its kinetic energy after the interaction *K''*, the kinetic energy of the atomic electron after the interaction *K'*, the angle at which the incoming electron departs after the interaction *θ''* and the angle at which the atomic electron is deflected *θ'*. In manual mode, the user enters a value for *K* and the other four values are calculated. In simulated mode, the user enters a value for *K* and the number of collisions to model, and the results are collected in a table and a series of one- and two-dimensional histograms.



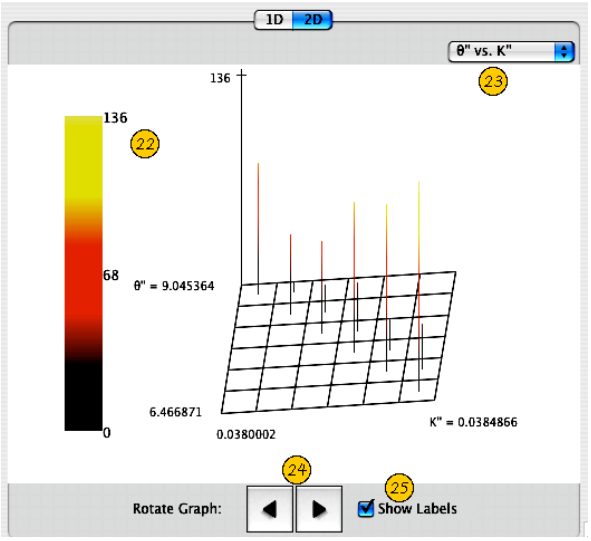
#	K	K''	K'	θ''	θ'
635	0.039	0.0384318	0.0005682	6.805305	82.93758
636	0.039	0.0383147	0.0006853	7.477558	82.24051
637	0.039	0.0381369	0.0008631	8.398715	81.28562
638	0.039	0.038433	0.000567	6.798316	82.94482
639	0.039	0.0383164	0.0006836	7.46829	82.25012
640	0.039	0.0381064	0.0008936	8.547257	81.13167

1. The animation window shows what happens when the particles interact.
2. This button starts and pauses the animation.
3. The manual and simulated radio buttons switch between manual and simulated mode.
4. The Speed slider controls the speed of the animation, as well as the speed of the simulation if you have chosen to simulate the events one at a time.
5. In this box, enter *K*.
6. This box displays *K''*.
7. This box displays *K'*.
8. This box displays *θ''*.
9. This box displays *θ''*.

Note: Enter a value for *K*. In manual mode, the other values will be calculated automatically. In simulated mode, also enter the number of interactions to simulate, then click the Simulate button to begin the calculations.

10. The Clear button clears the five input text boxes (numbers 5-9).
11. In simulated mode, the Simulate button begins the simulation based on the data entered (numbers 5-9), shows the results in the table and graph, and starts the animation. In manual mode, this becomes the Add to Chart button, and it adds the data from the five input text boxes (numbers 5-9) to the table.
12. In this box, enter the number of interactions to simulate.
13. Use these radio buttons to choose if the program simulates the events one at a time or all at once.
14. In this box, enter the desired lower boundary of the graph.
15. In this box, enter the desired upper boundary of the graph.
16. In this box, enter the desired number of bins of the graph.
17. These radio buttons let you choose which variable to update.
18. The Update button refreshes the graph with the new parameters (numbers 14-17).
19. The table tracks each result, and can be sorted according to any variable by clicking on the column header. To re-order the rows manually, click and drag a row to move it.
20. This button resets the chart and graphs.
21. The graph window shows the results through customizable one- or two-dimensional graphs. Toggle between 1D and 2D using the tabs at the top of the graph window. See below for 2D instructions.

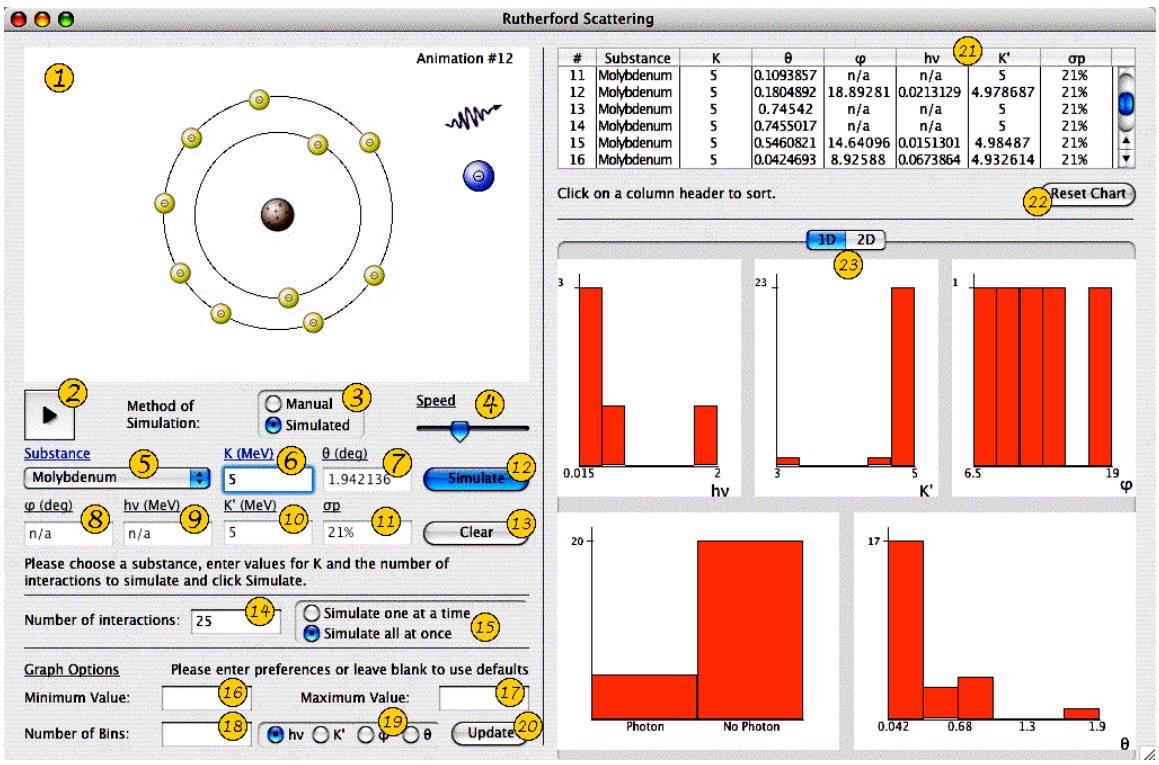
Møller Scattering: 2D Histogram



22. This legend shows how the height of a bar is related to its frequency.
23. Choose the graph with this popup menu.
24. These buttons rotate the graph clockwise and counter-clockwise.
25. This checkbox turns the labels on and off.

Rutherford Elastic Scattering (electrons)

Rutherford Scattering describes the interaction between the nucleus of a stationary atom (or molecule) and an incoming electron. The atom alters the electron's trajectory, and a photon may be emitted. It takes into account seven variables: the substance (which can be an atom, a molecule or a mixture) that scatters the electron, the kinetic energy of the incoming electron before the interaction K, the angle at which it is scattered θ, the angle of emission of the photon (if applicable) φ, the photon energy (if applicable) $h\nu$, the kinetic energy of the electron after the interaction K' and the probability that a photon will be emitted σp. In manual mode, the user enters a substance and a value for K, and the other five values are calculated. In simulated mode, the user enters a substance, a value for K and the number of collisions to model, and the results are collected in a table and a series of one- and two-dimensional histograms.



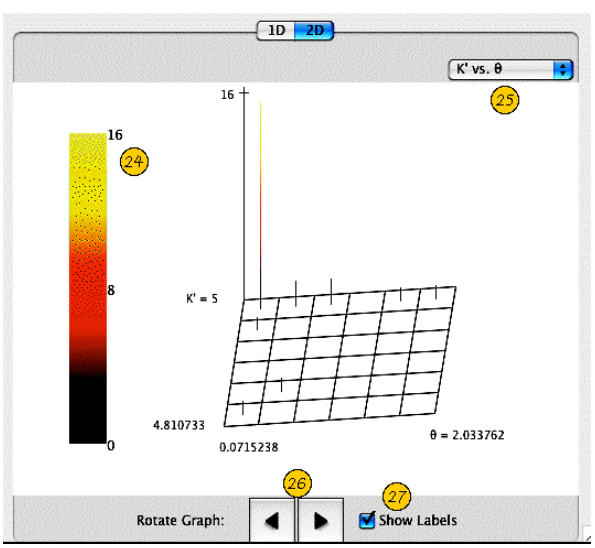
1. The animation window shows what happens when the particles interact.
2. This button starts and pauses the animation.
3. The manual and simulated radio buttons switch between manual and simulated mode.
4. The Speed slider controls the speed of the animation, as well as the speed of the simulation if you have chosen to simulate the events one at a time.
5. Choose the substance with this menu. If Other is chosen, choose a file that contains the appropriate information (see appendix for details).
6. In this box, enter K.
7. This box displays θ.
8. This box displays φ.

9. This box displays $h\nu$.
10. This box displays K'.
11. This box displays σp.

Note: Enter a substance and a value for K. In manual mode, the other values will be calculated automatically. In simulated mode, also enter the number of interactions to simulate, then click the Simulate button to begin the calculations.

12. The Clear button resets the menu (number 5) and clears the six input text boxes (numbers 6-11).
13. In simulated mode, the Simulate button begins the simulation based on the data entered (numbers 5-11), shows the results in the table and graph, and starts the animation. In manual mode, this becomes the Add to Chart button, and it adds the data from the menu (number 5) and the six input text boxes (numbers 6-11) to the table.
14. In this box, enter the number of interactions to simulate.
15. Use these radio buttons to choose if the program simulates the events one at a time or all at once.
16. In this box, enter the desired lower boundary of the graph.
17. In this box, enter the desired upper boundary of the graph.
18. In this box, enter the desired number of bins of the graph.
19. These radio buttons let you choose which variable to update.
20. The Update button refreshes the graph with the new parameters (numbers 16-19).
21. The table tracks each result, and can be sorted according to any variable by clicking on the column header. To re-order the rows manually, click and drag a row to move it.
22. This button resets the chart and graphs.
23. The graph window shows the results through customizable one- or two-dimensional graphs. Toggle between 1D and 2D using the tabs at the top of the graph window. See below for 2D instructions.

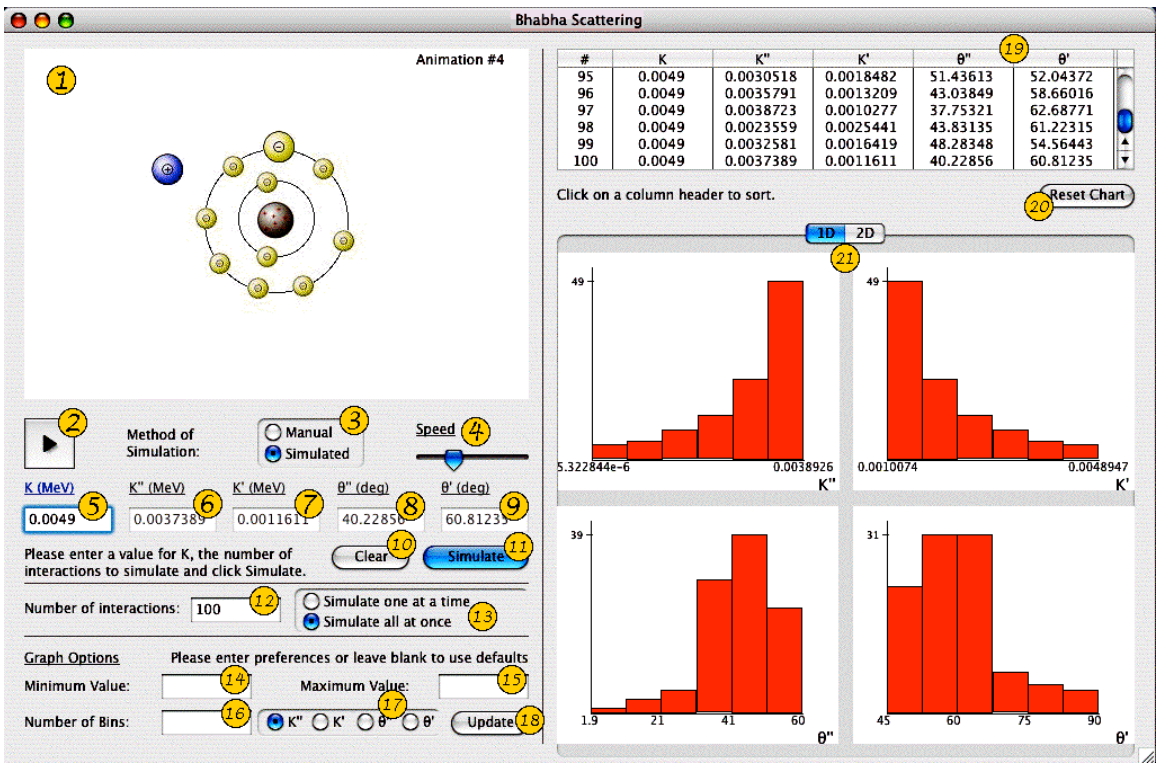
Rutherford Scattering: 2D Histogram



24. This legend shows how the height of a bar is related to its frequency.
25. Choose the graph with this popup menu.
26. These buttons rotate the graph clockwise and counter-clockwise.
27. This checkbox turns the labels on and off.

Bhabha Scattering (positrons)

Bhabha Scattering describes the interaction between a stationary atom and an incoming positron. The positron knocks one of the orbiting electrons out of its shell. It takes into account five variables: the kinetic energy of the incoming positron before the interaction *K*, its kinetic energy after the interaction *K''*, the kinetic energy of the atomic electron after the interaction *K'*, the angle at which the positron departs after the interaction *θ''* and the angle at which the electron is deflected *θ'*. In manual mode, the user enters a value for *K* and the other four values are calculated. In simulated mode, the user enters a value for *K* and the number of collisions to model, and the results are collected in a table and a series of one- and two-dimensional histograms.

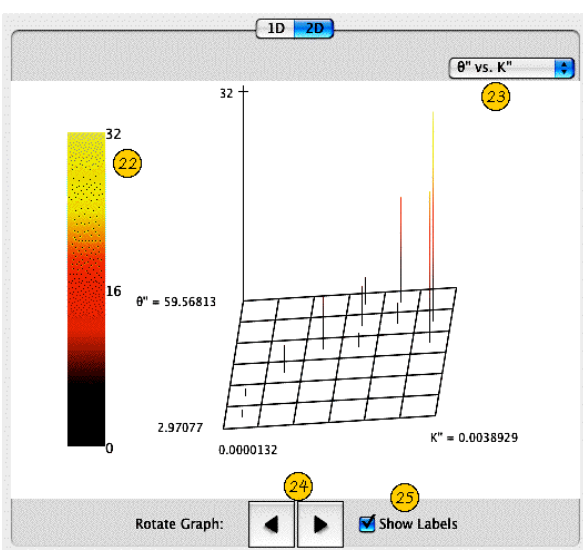


1. The animation window shows what happens when the particles interact.
2. This button starts and pauses the animation.
3. The Manual and Simulated radio buttons switch between manual and simulated mode.
4. The Speed slider controls the speed of the animation, as well as the speed of the simulation if you have chosen to simulate the events one at a time.
5. In this box, enter *K*.
6. This box displays *K''*.
7. This box displays *K'*.
8. This box displays *θ''*
9. This box displays *θ'*.

Note: Enter a value for *K*. In manual mode, the other values will be calculated automatically. In simulated mode, also enter the number of interactions to simulate, then click the Simulate button to begin the calculations.

10. The Clear button clears the five input text boxes (numbers 5-9).
11. In simulated mode, the Simulate button begins the simulation based on the data entered (numbers 5-9), shows the results in the table and graph, and starts the animation. In manual mode, this becomes the Add to Chart button, and it adds the data from the five input text boxes (numbers 5-9) to the table.
12. In this box, enter the number of interactions to simulate.
13. Use these radio buttons to choose if the program simulates the events one at a time or all at once.
14. In this box, enter the desired lower boundary of the graph.
15. In this box, enter the desired upper boundary of the graph.
16. In this box, enter the desired number of bins of the graph.
17. These radio buttons let you choose which variable to update.
18. The Update button refreshes the graph with the new parameters (numbers 14-17).
19. The table tracks each result, and can be sorted according to any variable by clicking on the column header. To re-order the rows manually, click and drag a row to move it.
20. This button resets the chart and graphs.
21. The graph window shows the results through customizable one- or two-dimensional graphs. Toggle between 1D and 2D using the tabs at the top of the graph window. See below for 2D instructions.

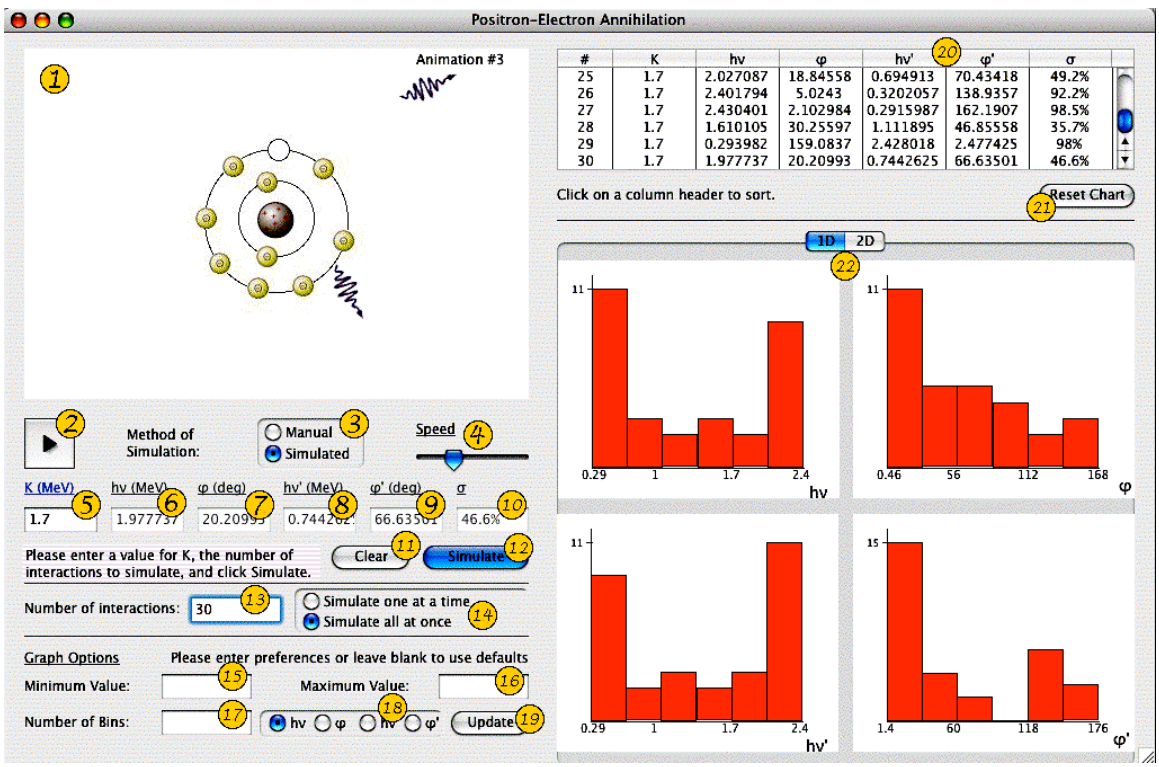
Bhabha Scattering: 2D Histogram



22. This legend shows how the height of a bar is related to its frequency.
23. Choose the graph with this popup menu.
24. These buttons rotate the graph clockwise and counter-clockwise.
25. This checkbox turns the labels on and off.

Positron-Electron Annihilation

Positron-Electron Annihilation describes the interaction between a stationary atom and an incoming positron. When the positron comes close to an electron, the two particles are annihilated, and two photons are emitted. It takes into account six variables: the kinetic energy of the incoming positron before the interaction K, the energy of one photon $h\nu$, the angle at which it is emitted φ, the energy of the other photon $h\nu'$, the angle at which it is emitted φ' and the relative probability of this event happening σ. In manual mode, the user enters a value for K and either $h\nu$ or φ and the other four values are calculated. In simulated mode, the user enters a value for K and the number of collisions to model, and the results are collected in a table and a series of one- and two-dimensional histograms.



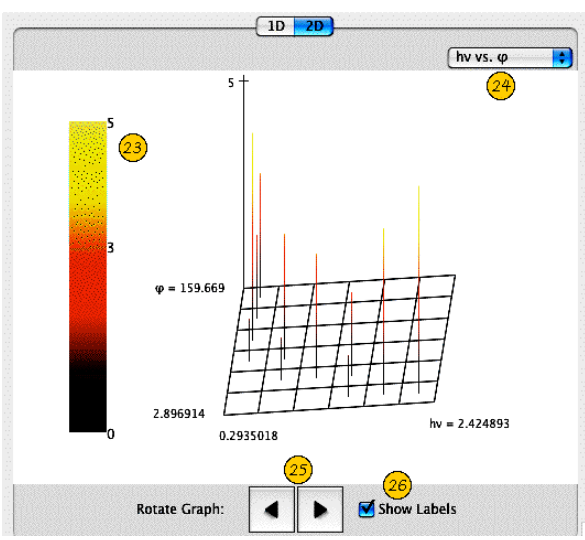
1. The animation window shows what happens when the particles interact.
2. This button starts and pauses the animation.
3. The manual and simulated radio buttons switch between manual and simulated mode.
4. The Speed slider controls the speed of the animation, as well as the speed of the simulation if you have chosen to simulate the events one at a time.
5. In this box, enter K.
6. In manual mode, you may enter $h\nu$ in this box; in simulated mode, $h\nu$ is displayed in this box.
7. In manual mode, you may enter φ in this box; in simulated mode, φ is displayed in this box.
8. This box displays $h\nu'$.

9. This box displays φ'.
10. This box displays σ.

Note: In manual mode, enter values for K, and either $h\nu$ or φ, and the other values will be calculated automatically. In simulated mode, enter a value for K and the number of interactions to simulate, then click the Simulate button to begin the calculations.

11. The Clear button clears the six input text boxes (numbers 5-10).
12. In simulated mode, the Simulate button begins the simulation based on the data entered (numbers 5-10), shows the results in the table and graph, and starts the animation. In manual mode, this becomes the Add to Chart button, and it adds the data from the five input text boxes (numbers 5-10) to the table.
13. In this box, enter the number of interactions to simulate.
14. Use these radio buttons to choose if the program simulates the events one at a time or all at once.
15. In this box, enter the desired lower boundary of the graph.
16. In this box, enter the desired upper boundary of the graph.
17. In this box, enter the desired number of bins of the graph.
18. These radio buttons let you choose which variable to update.
19. The Update button refreshes the graph with the new parameters (numbers 15-18).
20. The table tracks each result, and can be sorted according to any variable by clicking on the column header. To re-order the rows manually, click and drag a row to move it.
21. This button resets the chart and graphs.
22. The graph window shows the results through customizable one- or two-dimensional graphs. Toggle between 1D and 2D using the tabs at the top of the graph window. See below for 2D instructions.

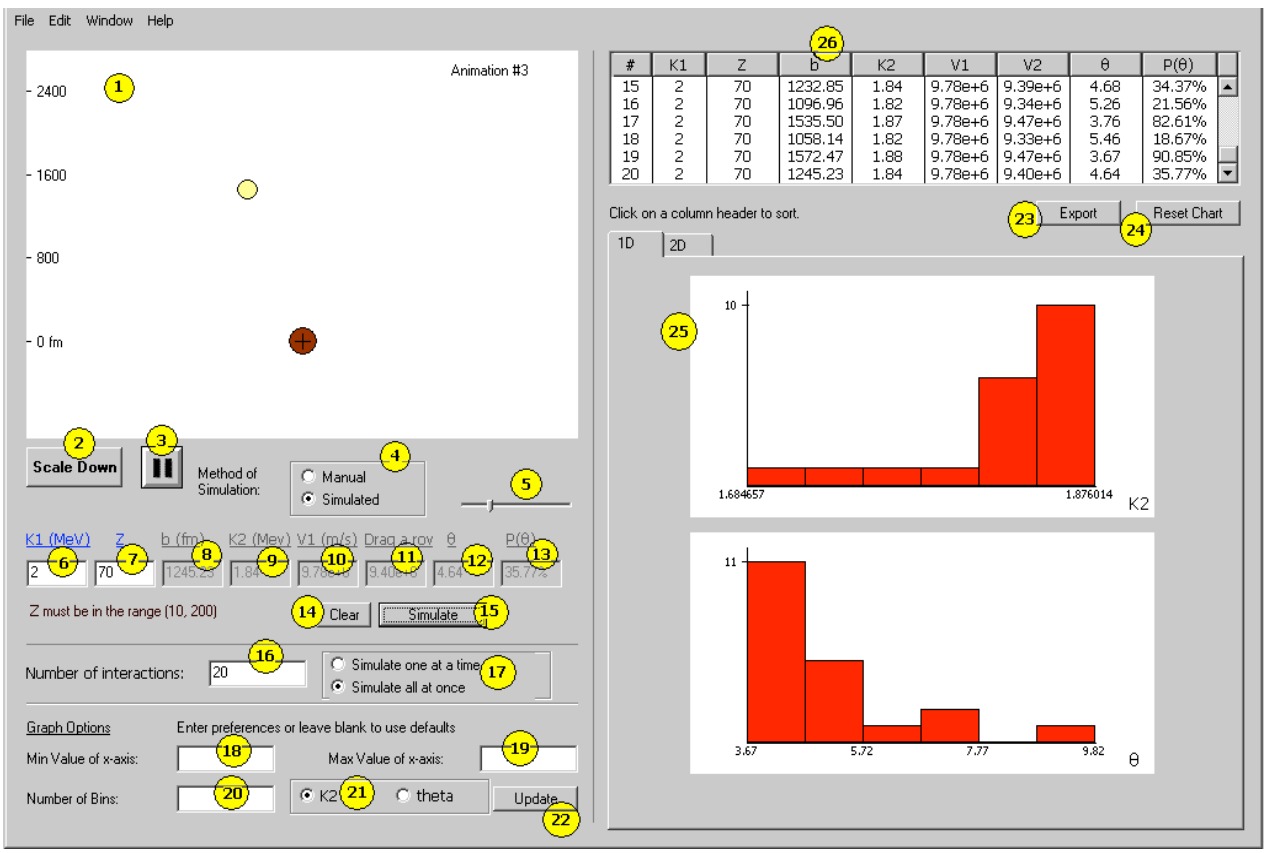
Positron-Electron Annihilation: 2D Histogram



23. This legend shows how the height of a bar is related to its frequency.
24. Choose the graph with this popup menu.
25. These buttons rotate the graph clockwise and counter-clockwise.
26. This checkbox turns the labels on and off.

Rutherford scattering (Alpha particles)

Rutherford scattering describes the interaction between a stationary nucleus and an incoming alpha particle. After the collision, the alpha particle scatters at an angle and the nucleus recoils. It takes into account eight variables: the initial alpha particle kinetic energy *K1*, the alpha particle kinetic energy *K2* after collision, the impact parameter *b* at which the alpha particle passes the nucleus, the atomic number *Z* of the atom that contains the nucleus, the initial alpha particle velocity *V1*, the alpha particle velocity *V2* after collision, the angle θ at which the alpha particle scatters, and the cumulative probability $P(\theta)$ of the events with scattering angle less than or equal to θ. In the manual mode, the user enters three variables *K1*, *b*, and *Z*, and the other five values are calculated. In the simulated mode, the user enters K1, Z, and the number of collisions to model, and the results are collected in a table and a series of one- and two-dimensional histograms.



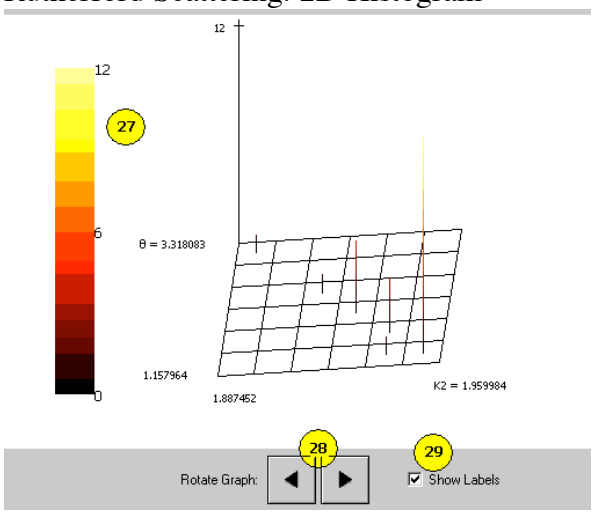
1. The animation window shows what happens when the particles interact.
2. This scale down button scales the animation window so as to let the user to see a clear and full range of the animation.
3. This button starts and pauses the animation.
4. The manual and simulated radio buttons switch between manual and simulated mode.

5. The Speed slider controls the speed of the animation, as well as the speed of the simulation if you have chosen to simulate the events one at a time.
6. In this box, enter the initial kinetic energy K1 of the incident alpha particle.
7. In this box, enter the atomic number *Z* of the atom that contains the nucleus.
8. In this box, enter the impact parameter b of the incident alpha particle.
9. This box displays the alpha particle kinetic energy K2 after collision.
10. This box displays the velocity V1 of the incident alpha particle.
11. This box displays the velocity V2 of the alpha particle after collision.
12. This box displays the scattering angle θ of the alpha particle.
13. This box displays the cumulative probability of the events with scattering angle less than or equal to scattering angle θ.

Note: In the manual mode, enter three values *K1, b,* and *Z*, and the other five quantities are calculated automatically. In the simulated mode, enter values for *K1*, *Z,* and the number of interactions to simulate, then click Simulate to begin the calculations.

14. The Clear button clears the eight input text boxes (numbers 6-13).
15. In the simulated mode, the Simulate button begins the simulation based on the data entered and calculated (numbers 6-13), shows the results in the table and graphs, and starts the animation. In the manual mode, this button becomes the Start Animation, it begins the simulation based on the data entered and calculated (numbers 6-13), shows the results in the table and starts the animation. Also in manual mode, there is one more button beside the Start Simulation button—Add to Chart button. This button adds the data from the eight input boxes (numbers 6-13) to the table.
16. In this box, enter the number of interactions to simulate.
17. Use these radio buttons to choose if the program simulates the events one at a time or all at once.
18. In this box, enter the desired lower boundary of a selected graph.
19. In this box, enter the desired upper boundary of a selected graph.
20. In this box, enter the desired number of bins of a selected graph.
21. These radio buttons let you choose which variable to update.
22. The Update button refreshes the graphs with the new parameters (numbers 18-21).
23. This button let the user export the data in the table and save it to a file through a dialog window.
24. This button resets the chart and graphs.
25. The graph window shows the results through customizable one- or two-dimensional graphs. Toggle between 1D and 2D using the tabs at the top of the graph window. See below for 2D instructions.
26. The table tracks each result, and can be sorted according to any variable by clicking on the column header. To re-order the rows manually, click and drag a row to move it.

Rutherford Scattering: 2D Histogram



27. This legend shows how the height of a bar is related to its frequency.
28. These buttons rotate the graph clockwise and counter-clockwise.
29. This checkbox turns the labels on and off.

APPENDIX

If Other is chosen from the substance menu in the Rutherford Scattering window, you must have a properly-formatted file with the appropriate information, and the extension ".brems". The following example is the file water.brems, which contains the information for water.

Water.brems

water.brems

```
// this file is used to determine the probability and data of a bremsstrahlung
photon for water
// it gives the number of constituents N, the Z and weight fraction P, and the
stopping powers
***
2
1	0.112
8	0.888
1.000E-02	3.898E-03	2.256E+01
1.250E-02	3.927E-03	1.898E+01
1.500E-02	3.944E-03	1.647E+01
1.750E-02	3.955E-03	1.461E+01
2.000E-02	3.963E-03	1.318E+01
2.500E-02	3.974E-03	1.110E+01
3.000E-02	3.984E-03	9.657E+00
3.500E-02	3.994E-03	8.596E+00
4.000E-02	4.005E-03	7.781E+00
4.500E-02	4.018E-03	7.134E+00
5.000E-02	4.031E-03	6.607E+00
5.500E-02	4.046E-03	6.170E+00
6.000E-02	4.062E-03	5.801E+00
7.000E-02	4.098E-03	5.211E+00
8.000E-02	4.138E-03	4.761E+00
9.000E-02	4.181E-03	4.407E+00
1.000E-01	4.228E-03	4.119E+00
1.250E-01	4.355E-03	3.596E+00
1.500E-01	4.494E-03	3.242E+00
1.750E-01	4.643E-03	2.988E+00
2.000E-01	4.801E-03	2.798E+00
2.500E-01	5.141E-03	2.533E+00
3.000E-01	5.514E-03	2.360E+00
3.500E-01	5.914E-03	2.241E+00
4.000E-01	6.339E-03	2.154E+00
4.500E-01	6.787E-03	2.090E+00
5.000E-01	7.257E-03	2.041E+00
5.500E-01	7.747E-03	2.003E+00
6.000E-01	8.254E-03	1.972E+00
7.000E-01	9.313E-03	1.926E+00
8.000E-01	1.042E-02	1.896E+00
9.000E-01	1.159E-02	1.876E+00
1.000E+00	1.280E-02	1.862E+00
1.250E+00	1.600E-02	1.845E+00
1.500E+00	1.942E-02	1.841E+00
1.750E+00	2.303E-02	1.844E+00
2.000E+00	2.678E-02	1.850E+00
2.500E+00	3.468E-02	1.868E+00
3.000E+00	4.299E-02	1.889E+00
3.500E+00	5.164E-02	1.910E+00
```

All lines before the "***" are comments, and not read by the program. The next line, "2" in this case, represents the number of elements that make up the substance. Following this line is one line for each element, in this case, they read "1 0.112" and "8 0.888". The first number represents the atomic number of the element and the second number represents the fraction of the total mass of the substance that is composed of this element. These numbers must be separated by Tabs. In this case, hydrogen makes up 11.2% of the mass of water, while oxygen makes up 88.8% of the mass. The remaining lines represent, from left to right, a kinetic energy K, the radiative stopping power of the substance for an electron with kinetic energy K, and the total stopping power of the subtance for an electron with kinetic energy K. These numbers must also be separated by Tabs.