Dual Scattering Foil Simulator User's Manual

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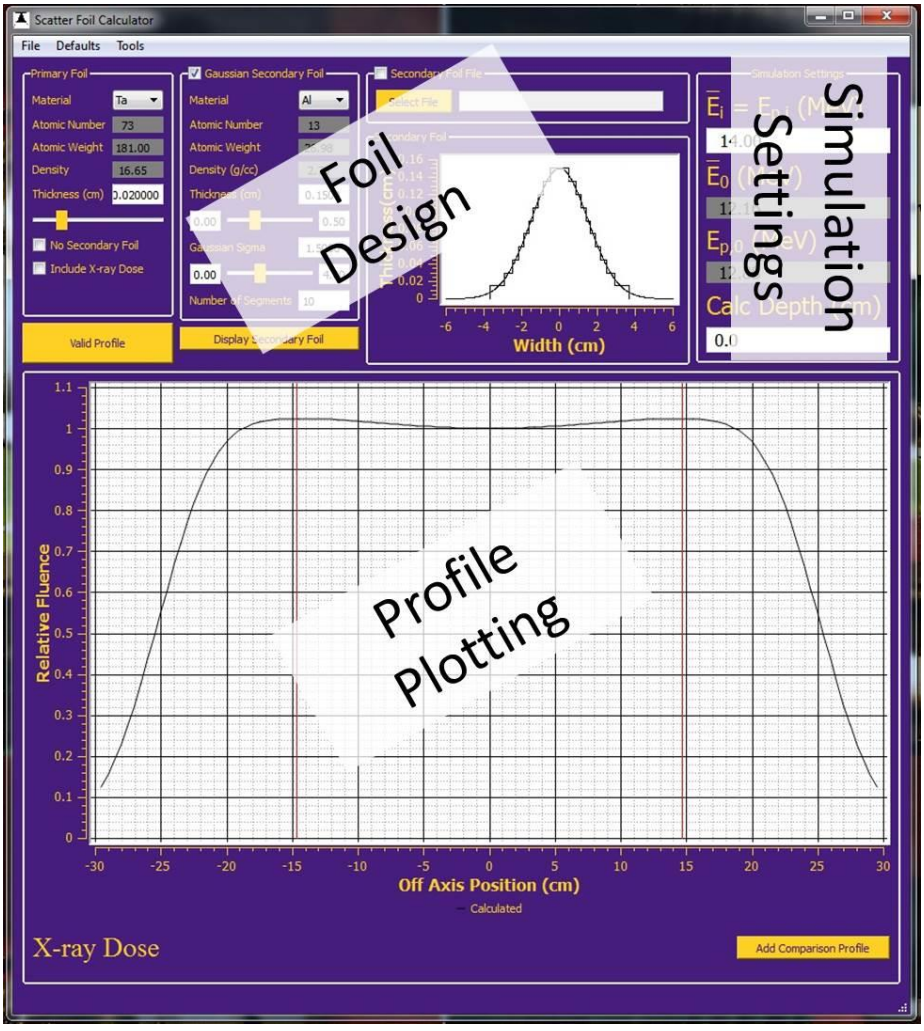
1. Introduction

The purpose of this document is to inform the user on how to generate the dual scattering foil simulator. The dual scattering foil simulator is a real-time, computer code that allows design of dual scattering foil system for the therapeutic electron beams in the range of 4-25 MeV. It is meant to be an educational or research tool for the radiation oncology medical physicist. The dual scattering foil simulator code is based on the fundamental physics of electron interactions (collisional energy loss, bremsstrahlung energy loss, and multiple coulomb scattering).

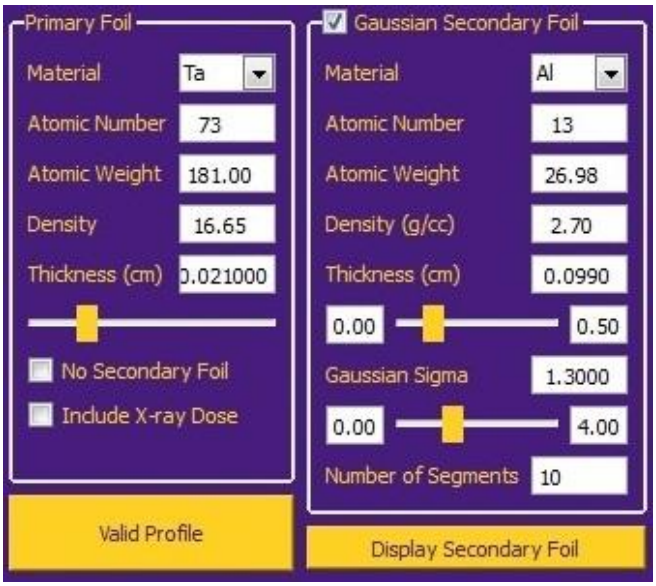
A more in depth description of the underlying physics and many of the simulator features can be found in the JACMP article "Real-time Simulator for Designing Electron Dual Foil Scattering Systems", which can be downloaded from the Dual Foil Simulator page on the electron therapy website (http://electronbeamtherapy.com/Dual%20Scattering%20Foils.php).

The simulator main screen has three major components, outlined in the image below: 1) Foil design, 2) Simulation settings, and 3) Profile Plotting. In order to generate a relative off-axis fluence/dose profile, the user must have defined a valid primary foil, secondary foil, and simulation settings.



2. Foil Design

The dual scattering foil design process consists of defining a primary and secondary foil. In the enlarged figure below the options for each of the foils is shown.



2.1. Primary Foil

The user must select the material of which the primary foil will be composed, which is done via the dropdown menu at the top of the primary foil pane. The program comes with several predefined materials, but the user can add or delete materials as needed. For instructions on adding or deleting materials see section 5.3 of this manual. Upon selection of the material, the program will automatically fill the atomic number, atomic weight, and density fields. These fields are not editable from the main page.

After selecting the material, the user must enter the thickness of the primary foil. This definition can be done by either manually keying the thickness directly into the thickness field or via the slider bar directly beneath. The slider bar is especially useful when real-time changes and results are desired, e.g. fine tuning the foil to achieve a desired off-axis dose profile.

In addition to physically defining the primary foil the user has two additional options available. First, the “No Secondary Foil” option allows the user to calculate the off-axis dose profile with the secondary foil removed. Second, the “Include X-ray Dose” option allows the user to add the off-axis photon dose to the electron off-axis profile calculation. Without this option selected, the simulator calculates relative electron fluence instead of relative total dose.

The button at the bottom of the primary foil pane functions mainly to inform the user if the off-axis profile plotted in the plotting pane is a valid profile. The button will turn red if the user needs to recalculate the profile because of a change to one of the foil parameters. If the calculated profile ever seems to have failed to be updated, the user can click this button to force an updated calculation.

2.2. Secondary Foil

2.2.1. Gaussian Foil

The user must select the foil composition from the same list of available materials. As with the primary foil, the user enters the secondary foil thickness on the central-axis by manually keying a value in the field or using the slider bar. However, for the secondary foil the user must also similarly enter the Gaussian sigma. In addition, both slider bars found in the secondary foil design pane are slightly different than those found in the primary foil pane. There are editable fields on either side of these sliders. These fields allow the user to determine the bounds of the sliders and gives the user the ability to adjust the values with a coarse of fine control.

Lastly, the user must enter the number of horizontal segments used to approximate the secondary foil. This setup is used because in practice secondary foils are a series of circular foils of different diameters stacked on top of each other. The more segments you use, the closer the foil comes to an actual Gaussian.

As with the primary foil, if a valid primary foil and beam have been defined, adjusting these slider bars will give near real-time update to the off-axis relative fluence/dose profile in the plotting pane. In addition, the plot of the shape of the cross-section of the secondary foil, immediately to the right of the secondary foil parameters will be automatically updated.

2.2.2. User-Defined Foil

The user also has the option in this pane of including a user-defined secondary foil that need not be Gaussian. However, any user defined foil must be cylindrically symmetric pyramid. To select this option, the user must click the check box next to “Secondary Foil File”. The “Select File” button will then be active and allow the user to search the computer for an appropriate input file. To go back to the Gaussian secondary foil, simply click the check box next to “Gaussian Secondary Foil”. A description of the necessary file format and an example input file can be found in Appendix A.1.

The “Display Secondary Foil” button functions to update the plot of the secondary foil if a change to the foil doesn’t automatically initiate a replot of the foil.

3. Simulation Settings

3.1. Main Page Variables

The upper right panel contains the simulation settings that are most commonly changed. Energies are calculated according to Carver et al. The user enters E_I and the simulator calculates E_0 and $E_{p,0}$. Energy calculations follow the ICRU Report 35. The variables are defined as follows:

E_i - The initial beam energy incident on the primary scattering foil, which equals the most probable beam energy since a monoenergetic beam is assumed.

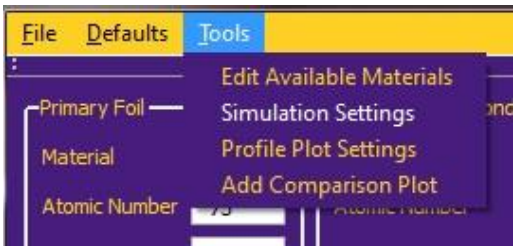
E_0 - The mean electron energy at isocenter.

$E_{p,0}$ - The most probable electron energy at isocenter.

Calc Depth - The depth in water beyond isocenter the user wishes to calculate the relative fluence/dose off-axis profile.

3.2. Additional Simulation Variables

In addition the main page simulation settings the user can change a variety of settings by selecting the “Tools” dropdown menu and the “Simulation Settings” sub menu as shown below:



This submenu brings up a new window (shown below) containing a variety of simulation setting options. Most of these options are described fully in Carver et al. with a few exceptions:

OA Flatness Extent – Defines how far from the center of the profile to evaluate the flatness criteria.

Flatness Criteria – Defines the tolerances that the user wants to use for acceptable flatness.

Reset to Default - Returns all settings to default settings contained in the *sim_defaults.dat* file.

Save as Default - Writes the current settings to the *sim_defaults.dat* file.

Update Settings – Button that saves the current settings for future simulations. This button must be pressed before exiting the screen in order to have any changes saved.

Finished – Closes this window.

4. Plotting

The bottom pane contains the plot of the relative fluence/dose off-axis profile determined by the user defined foils and simulation settings described previously. This panel also displays the central-axis X-ray dose component if the “Include X-ray Dose” box has been checked.

4.1. Adding a Comparison Profile

To add a comparison profile for the calculated profile the user can either select the "Add Comparison Profile" button in the lower right corner of the main window or select the "Add Comparison Plot" submenu under the "Tools" dropdown menu. These selections will open a file selection window to allow the user to locate the desired comparison profile. Two sample profiles are distributed with the installation. A description of the file format and an example comparison profile are found in Appendix A.2.

4.2. Determining Flatness

Adding a comparison profile allows the user to determine the flatness of the calculated profile. The flatness is calculated relative to the comparison profile. For ease, one of the sample profiles distributed with the program is a simple flat profile with all values equal to 1.0. Once a comparison profile has been loaded the user must click the green button in the "Primary Foil" panel to calculate the flatness. The flatness will show up directly beneath the profile plot. The extent over which the flatness is calculated and the deviation criteria is located in the "Simulation Settings" submenu under the "Tools" dropdown menu. The flatness is displayed as the maximum deviation above and below the comparison profile. If the deviation is within the user defined criteria the box will be displayed as green, and if the calculated profile fails the criteria the box will be displayed as red. If both the deviation above and below the comparison profile pass the flatness criteria the box containing the word "Flatness" will be green, otherwise red, as shown below:

5. Main Dropdown Menu

5.1. File

Set Working Directory – Allows the user to set the directory that the program will first look for files.

Set Save Directory – Allows the user to set the directory where the program saves files.

Exit – Closes the program

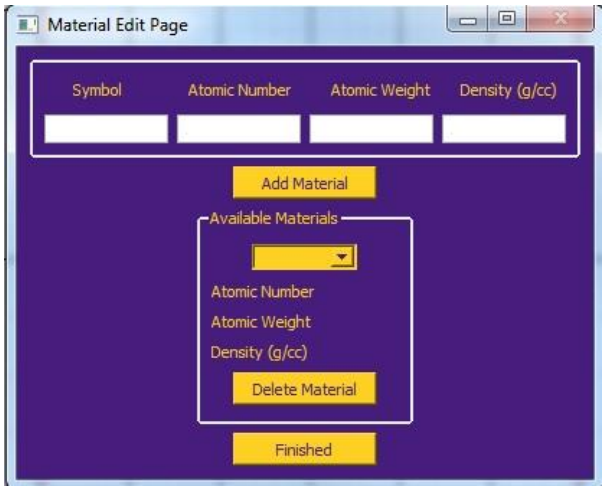
5.2. Defaults

Set Working Directory – Allows the user to set the default working directory

Set Save Directory – Allows the user to set the default save directory.

5.3. Tools

Edit Available Materials – Brings up a secondary window that allows the user to add, delete or change the materials available to the program, pictured below:



To add a material, the user enters the symbol, atomic number, atomic weight, and density in the fields provided. Then clicking the "Add material button" will include this material in the *Foil_Materials.dat* file and make it available for use in the simulator.

To delete a material, select the material from the dropdown menu located in the "Available Materials" panel. The program will list the atomic number, atomic weight and density below. Clicking the "Delete Material" button will remove this material from the *Foil_Materials.dat* file.

To exit this window the user must click the "Finished" button.

Simulation Settings – Brings up a secondary window that allows the user to modify the simulation settings. This window is described in Section 3.2.

Profile Plot Settings – Brings up a secondary window that allows the user to change the plotting ranges for the X-axis (off-axis position) and Y-axis (relative fluence/dose) for the profile plot.

Add Comparison Plot – Allows the user to select a profile for comparison with the calculated profile.

6. References

Carver R. L., Hogstrom K., Price M., LeBlanc J. and Pitcher G., “Real-Time Simulator for Designing Electron Dual Scattering Foil Systems.” J App Clin Med Phys. **15**. 323-42 (2014).

Whycoff H. O., A. Allisy R. S. C. and Adams G. E. D., ”Radiation Dosimetry: Electron Beams with Energies between 1 and 50 Mev.” **35**. (Bethesda, Maryland). ICRU (1984).

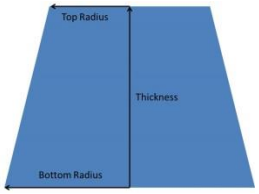
Appendix A: File Format Examples

A.1. Secondary Foil

A user defined secondary foil must be contained in a file with the following format with one line for each layer and the topmost layer coming first:

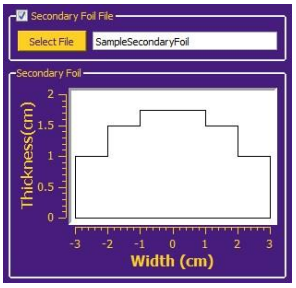
Top Radius (cm), Bottom Radius (cm), Thickness (cm), Atomic Number, Atomic Weight (g), Density (gm cm^{-3}).

The different definitions for top and bottom radius allow for an inclusion of a trapezoidal layer. These variables are depicted in the figure below:



SampleSecondaryFoil.txt: A sample secondary foil composed of Aluminum

1.0,1.0,0.25,13,26.98,2.7
2.0,2.0,0.5,13,26.98,2.7
3.0,3.0,1.0,13,26.98,2.7



A.2 Comparison Plots

A comparison plot file has the format and should have the extension .profile:

Off Axis Position (cm) Relative Off-Axis Value

SampleComparisonPlot.profile: This sample comparison plot only covers from 10.0 to 0 off-axis but that can be extended to whatever the user desires.

-10.000000 0.983604

-9.500000 0.986036

-9.000000 0.988520

-8.500000 0.990984

-8.000000 0.993349

-7.500000 0.995536

-7.000000 0.997480

-6.500000 0.999126

-6.000000 1.000440

-5.500000 1.001410

-5.000000 1.002041

-4.500000 1.002359

-4.000000 1.002406

-3.500000 1.002235

-3.000000 1.001907

-2.500000 1.001488

-2.000000 1.001042

-1.500000 1.000626

-1.000000 1.000291

-0.500000 1.000075

0.000000 1.000000