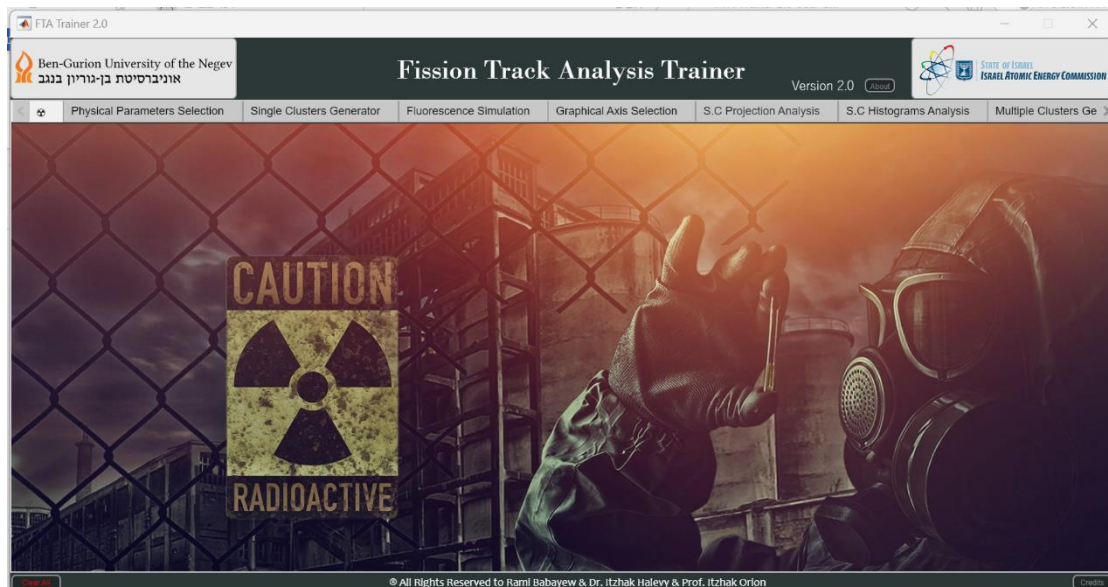




# אוניברסיטת בן-גוריון בנגב Ben-Gurion University of the Negev

The Faculty of Engineering  
Nuclear Engineering Unit

## FTA Trainer Application Version 2.0 User Guide



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***Supervisors:*** Prof. Itzhak Orion, Dr. Itzhak Halevy

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## Table of Contents



# 1. Introduction

## 1.1. Overview

Variants of the Fission Track Analysis (FTA) methodology have been used for decades in many fields, such as nuclear forensics, safeguards investigations, radiometry, geology, and cosmology. A fission-track (FT) is a microscopic-scale radiation-damaged site, which can be induced on a solid-state nuclear track detector – SSNTD (e.g., polycarbonate sheet, mica, etc.) by a radiant array of nuclear fissions of a single particle under thermal neutron flux. In nuclear forensics, the tracks are developed and made visible by chemical etching of the SSNTD. Since an FT cluster arises from a single particle, it exhibits a stochastically round shape, which defines both the presence and the location of a POI. When detected with transparent or translucent SSNTDs, FTs have optical characteristics that enable their visualization and identification using transmitted or reflected light microscopy.

The FTA Trainer is a cutting-edge simulation software application for nuclear forensics modeling. The software was developed using MATLAB App Designer infrastructure. The Application is exported as an executable file and can run on Windows-based computer without any specific environment or infrastructure.

The application utilizes a versatile database based on Monte Carlo simulations and can be used for research purposes and employee training in nuclear forensics as well. For example, it's possible to simulate fission tracks accurately based on physical and radiation parameters, resembling light microscope images. These serve as foundational data for AI-driven decoder software and image analysis.

Calculations can be made based on accurate real data. For example, by entering the diameter of the Fissile Material, Thermal neutron flux, Fission cross-section (Selectable between  $^{235}\text{U}$ ,  $^{233}\text{U}$ , and  $^{239}\text{Pu}$ ), Radiation time, and Fissile material mass, it is possible to calculate the number of tracks that are produced in a simulated Cluster.

The simulation shows the spatial behavior of the fission products and the plane projection. In addition, it emphasizes the different appearance of the clusters depending on the distance between the fissile material and the SSNTD.



Using the FTA Trainer, the following options are configurable and simulations can be made based on specific parameters which the user demands:

1. Size of a fissile particle.
2. Enrichment.
3. Mass of the fissile particle.
4. Specific fissile isotope (Selectable between  $^{235}\text{U}$ ,  $^{233}\text{U}$ , and  $^{239}\text{Pu}$ ).
5. Neutron flux.
6. Energy of neutrons.
7. Neutron flux radiation duration.
8. Geometric Parameters.
9. Multi Cluster generator (arbitrary and systematic).
10. Different depths and slices of particle in the sample foil.
11. 3-Dimensional visualization of the fission clusters.
12. 3-Dimensional visualization of the fissions in the radiated particle.
13. Projection of upper and lower SSNTD detectors.
14. Nearness test for detecting potential overlapped clusters.
15. Etching time influence on clusters based on semi-empiric experiment.
16. ROI Cutting estimation ideal areas.
17. Employee certification test.

In addition, the following parameters can be Calculated:

1. Calculation of a number of tracks based on physical parameters.
2. Calculation of total fissile mass of a batch of clusters.
3. Mini bulk and Micro bulk.
4. Histograms of the fission products track lengths and the projected length on the SSNTD (after 3-dimensional slicing).
5. Finale score for tested employee.

By bridging theory and application, the software enhances nuclear forensics investigations, contributing to nuclear security and nonproliferation efforts. This versatile and accurate tool promises deeper insights and robust methodologies in nuclear forensics.



## 1.2. System Requirements

Minimum computer requirements:

1. Intel® Core™ i7-1065G7 CPU 1.50 GHz.
2. RAM: 16 GB.
3. Windows 10 operating system.
4. Free space memory: 5 GB.

Recommended computer requirements:

1. Intel® Core™ i9-13900HX.
2. RAM: 32 GB.
3. Windows 10 operating system.
4. Free space memory: 5 GB.

Note: IOS עובד כגם ב



### 1.3.Installation

Explain how users can download, install, and set up your app on their devices.

## 2. Getting Started

The app based on visual components lay out design, creating a user-friendly graphical user interface. By entering to the app, the main screen shows up as shown in [?](#).

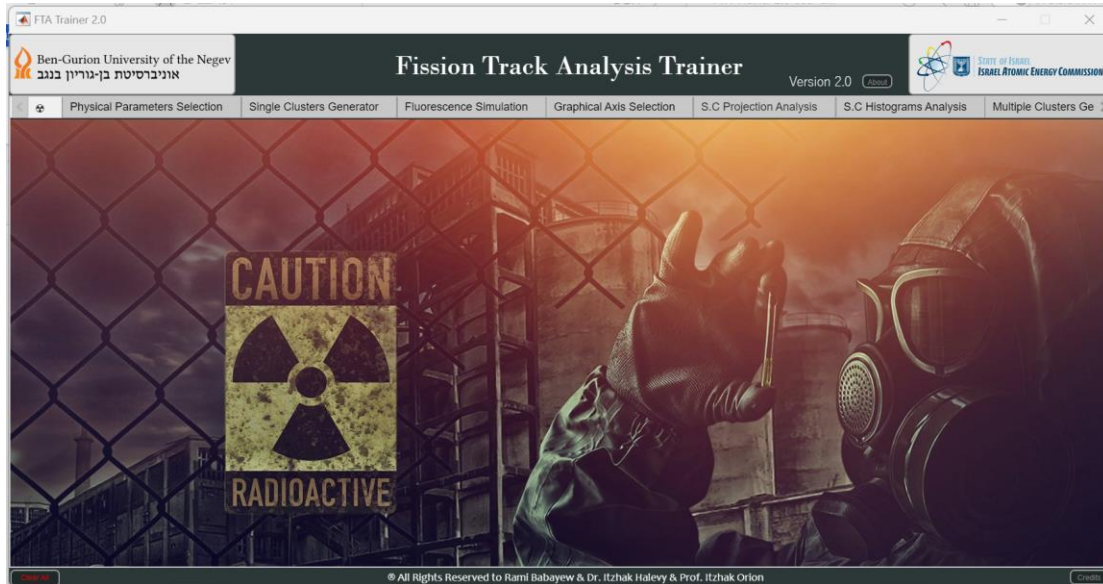


Figure 1. Main Screen of the FTA Trainer Application

The functionality in the application divided into 13 Tabs which the user can chose, depending on the functionality needed. By entering the tab on the upper side of the window, using the PC mouse, the application will open the chosen function tab. For convenience, it's possible to pick "remote" tabs faster by pressing one of the arrows, which opens a shortcut list of all the tabs, as show in [?](#).

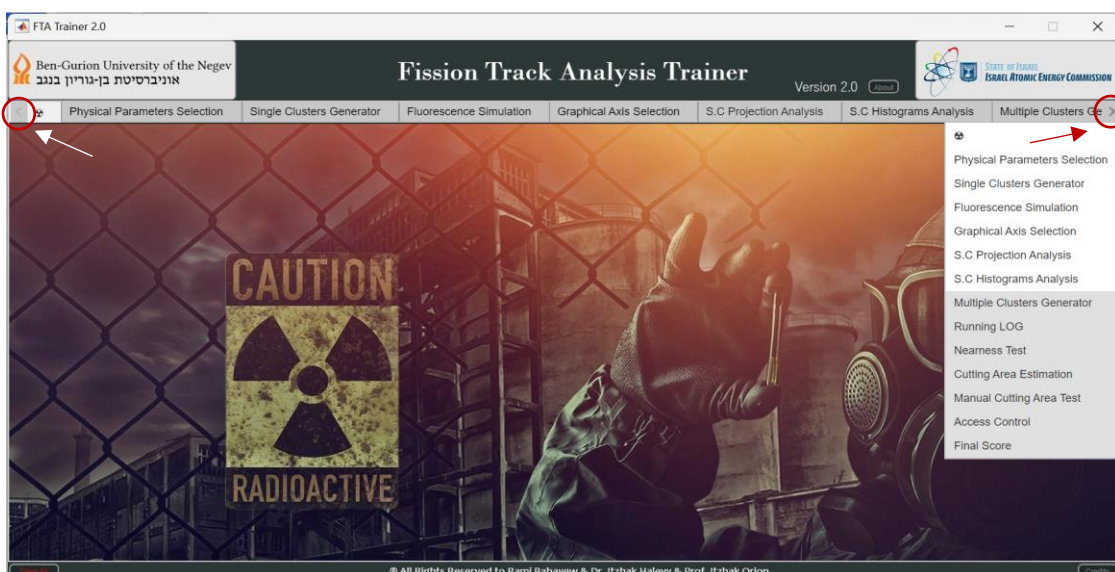


Figure 2. Main Screen of the FTA Trainer Application displaying shortcut list of the functionality tabs

## 2.1. Physical Parameters Tab

In this Tab, particle properties calculations can be made based on real given data. The calculations based on nuclear and particle physics theories according to proven equations. See ?.

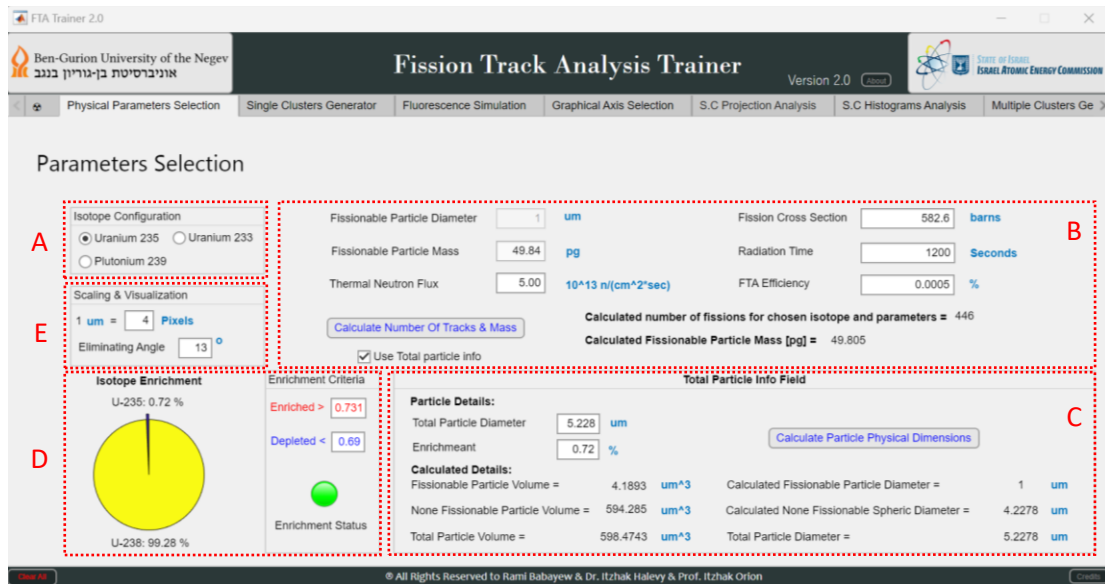


Figure 3. Physical Parameters Tab

In **Section A**, the user has the option to select from three different simulated isotopes:  $^{235}\text{U}$ ,  $^{233}\text{U}$ , and  $^{239}\text{Pu}$ . Each of these isotopes has unique properties and applications in the field of nuclear physics and engineering.

In **Section B** it's possible to calculate the Number of Tracks which can be produced in a simulated Cluster. When the check box 'Use Total particle info' isn't selected () , the user can enter any configuration desired. After choosing the parameters, by entering 'Calculate Number of Tracks & Mass' button, the app will calculate the number of tracks for the specific configuration.

In **Section C**, by choosing desired total particle diameter and enrichment and entering 'Calculate Particle Physical Dimensions' will calculate the particle physical dimensions. Calculating the diameter of fissile material involves considering it as a spherical object with the fissile substance located at its center. In this scenario, we assume the absence of any neutron-absorbing materials within the sphere. It's possible to use the parameters from Section C in Section B by Selecting the check box 'Use Total particle info' () .

**Section D** making visualization of the selected enrichment in pie percentage diagram. The enrichment status lamp will be *Green* when the particle is with natural enrichment,



**Blue** when the particle is depleted and **Red** when the particle enriched. The user can choose in this section the enrichment boundaries.

**Section E** responsible for visualization preferences for another Tabs, will be discussed later.

## 2.2. Single Clusters Generator Tab

The Single Clusters Generator Tab allows users to create customizable single clusters by specifying either a chosen number of tracks or utilizing the automatically calculated number of tracks from the Physical Parameters Tab.

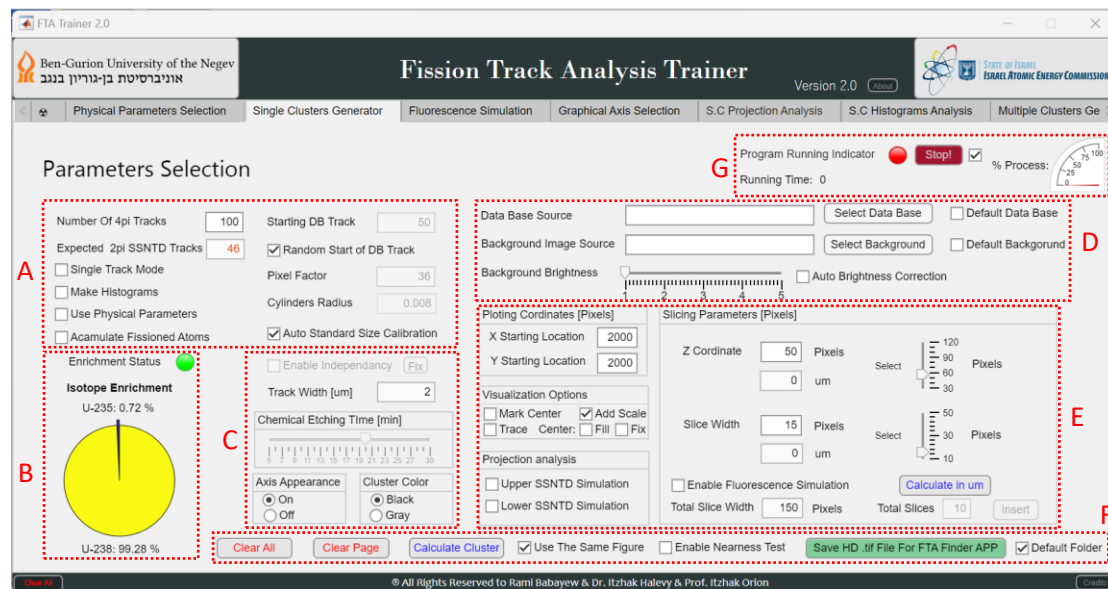


Figure 4. Single Clusters Generator Tab

As default, the application has stored data base of  $^{235}\text{U}$  particle, with diameter of ?um, with X % Enrichment, with Y events (simulated fissions).

Sections G and B share similarities with other Tabs, so there's no need to reiterate them.

### 2.3. Fluorescence Simulation Tab

Since the SSNTD is transparent its possible with real samples to generate an image which is three dimensional by using in depth auto focusing (Z-Stack) of the microscope. Fluorescence Simulation Tab is a tool for simulating this scenario.

When the check box 'Enable Fluorescence Simulation' is selected () in Section E of the Single clusters Tab, the app will perform Z-Stack 3-Dimensional visualization simulation which demonstrates the repetitiveness of the track's lengths, identified by colors. The simulation will appear in **Section A**. See **?**.

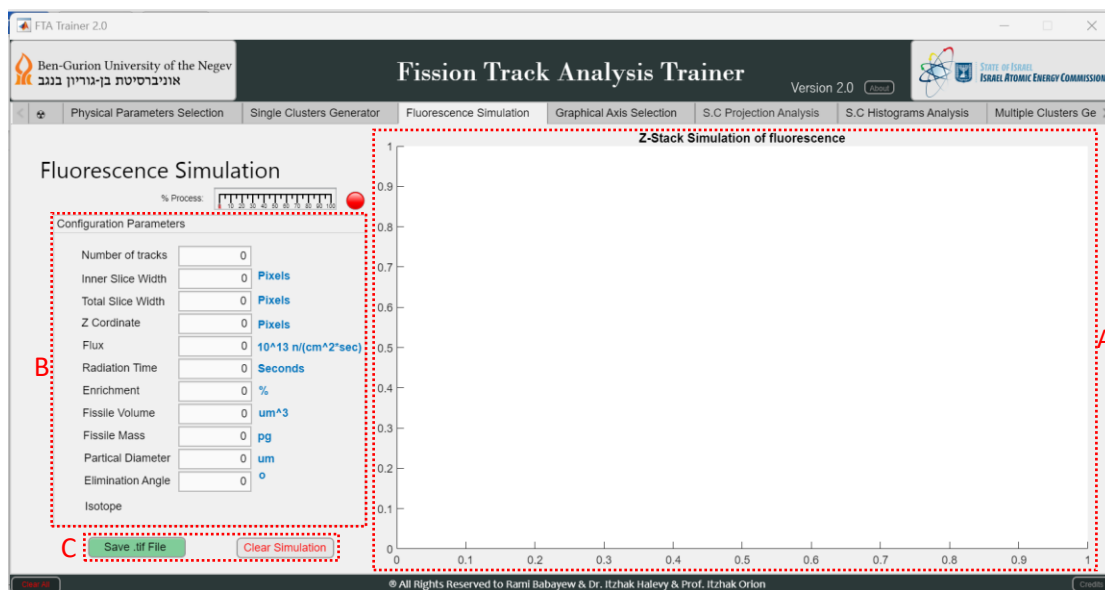


Figure 5. Physical Parameters Tab

**Section B** summarizes all the relevant data of the simulated particle.

**Section C** enables the user to clear the simulation or to save a '.tif' file of the simulation.



## 2.4. Graphical Axis Selection Tab

**Graphical selection of coordinates**

**Instructions to generate single cluster:**

1. Select Background.
2. Press the orange button below to generate the image.
3. Move the mouse to wanted position.
5. Press 'ENTER' on the keyboard.
6. If the selected coordinates are O.K., the program will enable to press the green button below.
7. Press 'Use Selected Position' button below.
8. Press the 'Calculate Cluster' button below and wait while the cluster generates.

**Selected Coordinates (SC)**

X:  Pixels  
Y:  Pixels

**Current Mouse Position**

X:  Pixels  
Y:  Pixels

**Random Calculation (MC)**

Mark Center

**Background Photo Source** |  |  |  |  |

**Progress:** % S.C Process: [Progress Bar] % M.C Process: [Progress Bar]

**Cluster Selection:**  Multi  Single



## 2.5. Single Clusters Projection Analysis Tab

FTAT Trainer 2.0

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Fission Track Analysis Trainer  
Version 2.0

STATE OF ISRAEL  
ISRAEL ATOMIC ENERGY COMMISSION

Physical Parameters Selection | Single Clusters Generator | Fluorescence Simulation | Graphical Axis Selection | **S.C Projection Analysis** | S.C Histograms Analysis | Multiple Clusters Ge

Analysis of Single Cluster

Program Running Indicator ● % Process: 0 25 50 75 100 Stop!

**B**

Upper Zr Simulated Tracks of Fission Products

**B1** Save .tif File Clear Simulation

**A**

Fissioned Atoms in Simulated Material Source

**A1** Save .tif File Clear Simulation

**C**

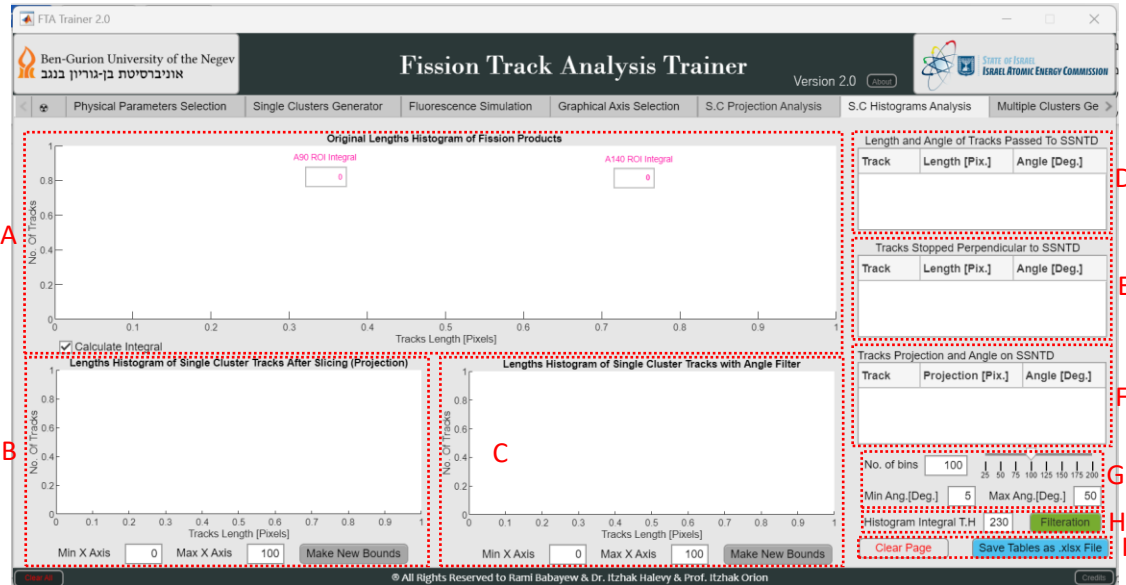
Lower Zr Simulated Tracks of Fission Products

**C1** Save .tif File Clear Simulation

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## 2.6. Single Clusters Histogram Analysis





## 2.7. Multiple Clusters Generator Tab

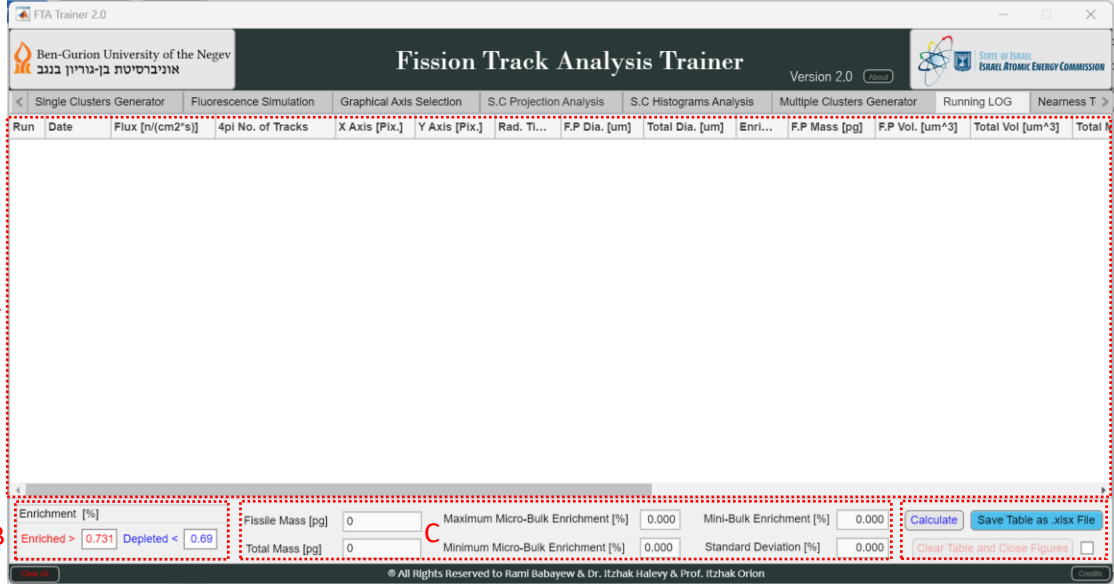
The screenshot displays the 'Multiple Clusters Generator' tab within the 'Fission Track Analysis Trainer' software. The interface is divided into several sections for parameter selection:

- General Parameters:** Number of Clusters (10), Max Number Of 4pi Tracks (50), Starting DB Track (50).
- Enrichment and Physical Parameters:** Enrich. Min/Max [%] (0.6, 0.8), Pixel Factor Range (10, 40), Pixel Factor (36), Cylinders Radius (0.008), Track Width [um] (2), Chemical Etching Time [min] (slider).
- Calibration and Axes:**  Auto Standard Size Calibration, X Axis Step (150), Y Axis Step (150).
- Batching and Visualization:** Automatic Batch (Starting X Axis: 500, Starting Y Axis: 500), Visualization Options (Add Scale checked, Fill unchecked).
- Random Batch Parameters:** Random Tracks No., Use Max Number, Mark Center, Tracks Min Value (10).
- Background and Slicing:** Background Image Source, Background Brightness (slider), Batch Slicing Parameters (Z Depth Range: 0-50, Z Coordinate: 50, Slice Width: 15).
- Isotope Enrichment:** A circular gauge shows U-235: 0.72% and U-238: 99.28%.
- Program Running Indicator:** Shows 'Stop!' and 0% Process, 0 of 0.

Buttons at the bottom include 'Clear All', 'Clear Page', 'Calculate Auto Clusters', 'Calculate Random Clusters', and 'Save HD .tif File For FTA Finder APP'.



## 2.8. Running LOG Tab



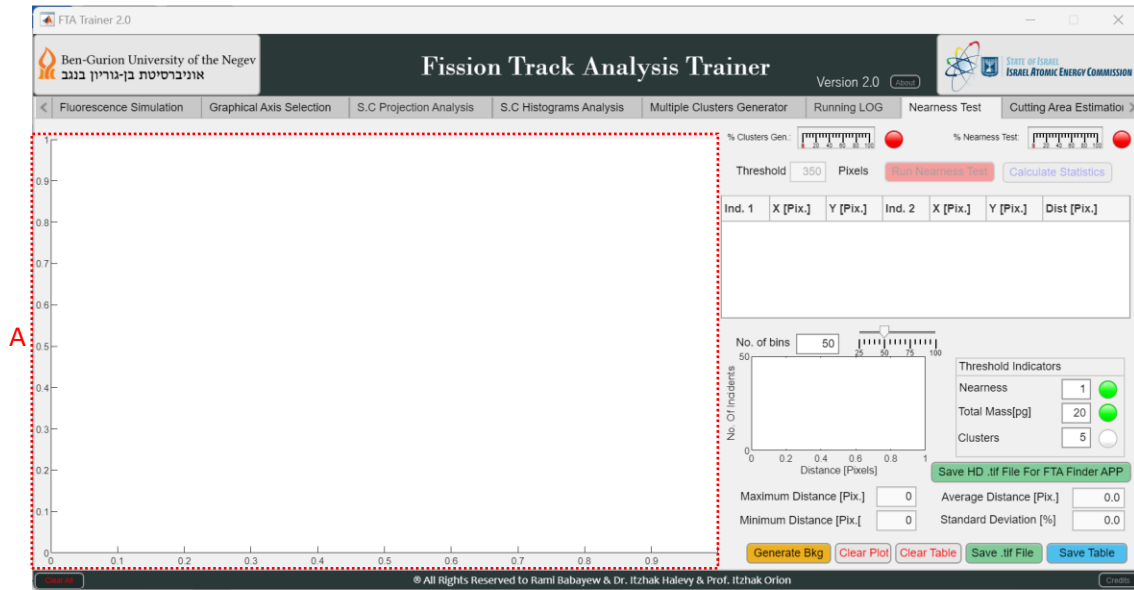
The screenshot shows the 'Running LOG' tab in the FTA Trainer 2.0 software. The interface includes a menu bar with options like 'Single Clusters Generator', 'Fluorescence Simulation', 'Graphical Axis Selection', 'S.C Projection Analysis', 'S.C Histograms Analysis', 'Multiple Clusters Generator', 'Running LOG', and 'Nearness T'. Below the menu is a table header with columns: Run, Date, Flux [n/(cm<sup>2</sup>s)], 4pl No. of Tracks, X Axis [Pix.], Y Axis [Pix.], Rad. Ti..., F.P Dia. [um], Total Dia. [um], Enri..., F.P Mass [pg], F.P Vol. [um<sup>3</sup>], Total Vol [um<sup>3</sup>], and Total M. The main area of the table is currently empty. At the bottom, there is a control panel with several input fields and buttons:

- Enrichment [%]: Enriched > 0.731, Depleted < 0.69
- Fissile Mass [pg]: 0
- Total Mass [pg]: 0
- Maximum Micro-Bulk Enrichment [%]: 0.000
- Mini-Bulk Enrichment [%]: 0.000
- Minimum Micro-Bulk Enrichment [%]: 0.000
- Standard Deviation [%]: 0.000
- Buttons: Calculate, Save Table as .xlsx File, Clear Table and Close Figures

Red dashed boxes and letters A, B, C, and D are used to highlight specific areas: A highlights the main table area, B highlights the enrichment input fields, C highlights the mass and enrichment input fields, and D highlights the calculation and save buttons.

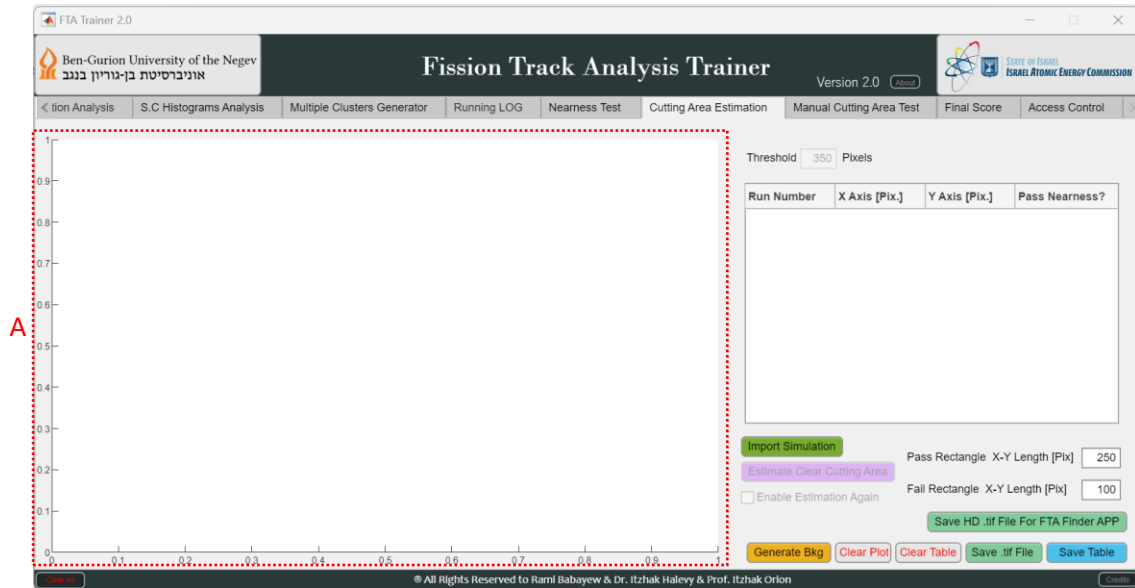


## 2.9. Nearness Test Tab



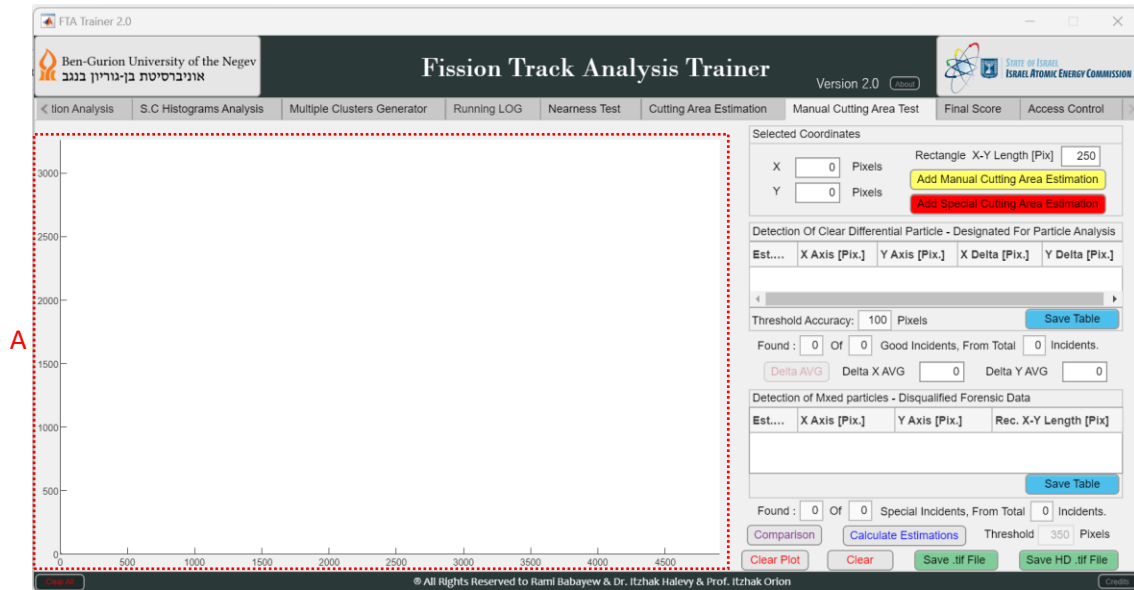


## 2.10. Cutting Area Estimation Tab





## 2.11. Manual Cutting Area Test Tab



The screenshot shows the 'Manual Cutting Area Test' tab in the FTA Trainer 2.0 software. The main window features a coordinate grid with X and Y axes ranging from 0 to 4500 and 0 to 3000 respectively. A red dashed rectangle is drawn on the grid, with a red letter 'A' pointing to its left vertical edge. The right-hand panel contains several sections:

- Selected Coordinates:** Includes input fields for X (0) and Y (0) in Pixels, and a 'Rectangle X-Y Length [Pix]' set to 250. It features two buttons: 'Add Manual Cutting Area Estimation' (highlighted in yellow) and 'Add Special Cutting Area Estimation' (highlighted in red).
- Detection Of Clear Differential Particle - Designated For Particle Analysis:** Contains a table with columns: Est..., X Axis [Pix.], Y Axis [Pix.], X Delta [Pix.], and Y Delta [Pix.]. Below the table are controls for 'Threshold Accuracy: 100 Pixels' (with a 'Save Table' button), 'Found: 0 Of 0 Good Incidents, From Total 0 Incidents.', and 'Delta AVG' controls for X and Y.
- Detection of Mxed particles - Disqualified Forensic Data:** Contains a table with columns: Est..., X Axis [Pix.], Y Axis [Pix.], and Rec. X-Y Length [Pix.]. Below the table are controls for 'Found: 0 Of 0 Special Incidents, From Total 0 Incidents.', 'Comparison', 'Calculate Estimations', 'Threshold: 350 Pixels', and buttons for 'Clear Plot', 'Clear', 'Save .tif File', and 'Save HD .tif File'.

At the bottom of the window, a copyright notice reads: © All Rights Reserved to Rami Babayew & Dr. Itzhak Halevy & Prof. Itzhak Orion.



## 2.12. Final Score Tab

After completing a test within the 'Manual Cutting Area Test' Tab, users have the option to assess the accuracy of their suggested cuttings by clicking the 'Import Results' button (A1). This action allows the software to import the user's recommendations and compare them against ideal cutting solutions. The process generates seven parameters, each representing a critical criterion evaluated in **Section A**.

By selecting the 'Calculate' button (B1), the software computes additional intermediate parameters based on the seven criteria and presents a score percentage on the left side of **Section B**. Finally, by pressing the 'Final Score' button (C1), the software calculates the ultimate score.

Users can also choose the level of expertise for the tested personnel, whether it's 'Rocky,' 'Certified,' or 'Expert.' Keep in mind that higher expertise levels entail more stringent test requirements.

See ?.

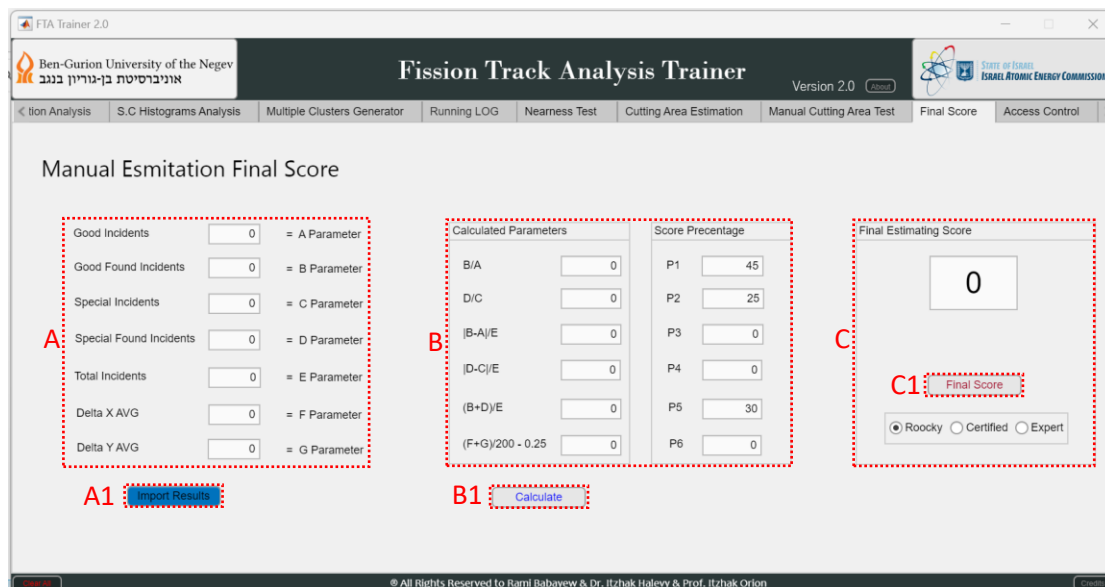


Figure 6. Manual Estimation Final Score Tab



### 2.13. Access Control Tab

This tab provides users with control over the accessibility of critical functions within the application. Additionally, it offers users the ability to assess their computer's memory usage, providing an indication of the application's performance during simulations, whether it will run smoothly or with potential slowdowns.

**Section A:** In this section the user can change access level from Employee level to Administrator level. By default, the application running with Employee level access, to change it the user need to enter a 6-digit password: "220495" and press the 'Enter' Button.

In FTA Trainer Version 2.0, there are only 2 functions that accessible by switching to Administrator level:

- The option to do comparison between user's estimation cuts and the ideal cuts in the "Manual Cutting Area Test" Tab.
- The Option to Change the values in all the fields of the 'Manual Estimation Final Score' Tab.

**Section B:** In this section it's possible to check the Read Access Memory of the computer by clicking the 'Check Usage' button. It is strongly advised to inspect memory usage before launching the application. If memory usage exceeds 60%, it is advisable for the user to consider freeing up memory space before initiating any simulations.

See [?](#).

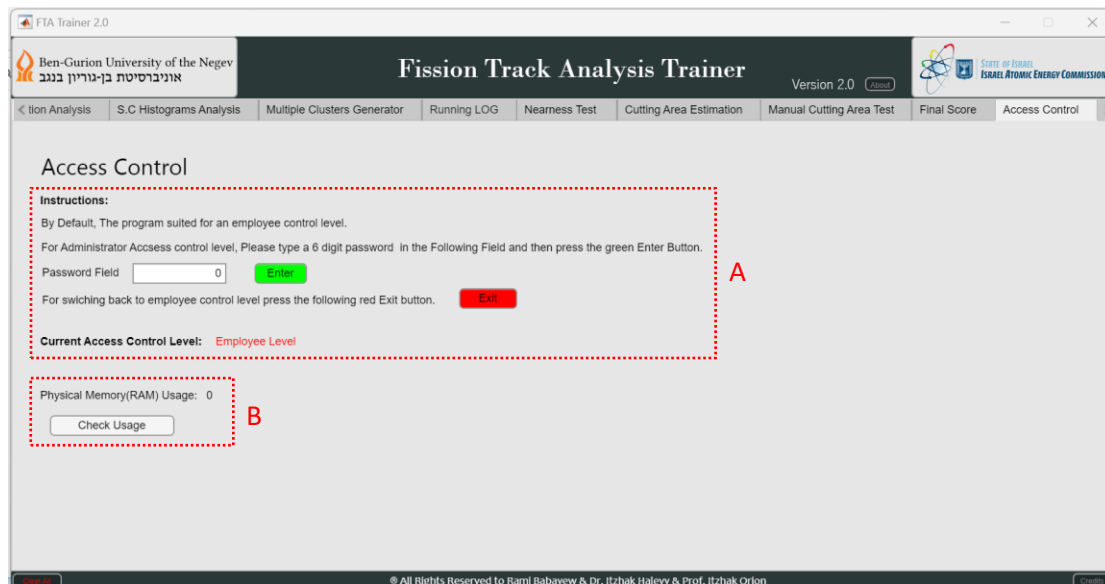


Figure 7. Access Control Tab



## 2.14. FTA Trainer General Buttons

The application has 3 general buttons:

**Button A:** "Clear All" button, serves as a function to reset the fields across all Tabs. It effectively erases the software's memory and restores all background parameters to their initial state, acting as a form of system restoration.

**Button B:** "About" button, in providing users with information about the application itself. After clicking the button, it shows essential details about the application, such as its name, version number, and copyright information. This helps users quickly identify which version of the application they are using. "About" button serves as an information hub, offering transparency, contact options, and valuable resources to users. It enhances the user experience by providing access to essential information.

**Button C:** Users may want to know who developed the application. The "Credits" section includes information about the companies and the individuals responsible for the software's creation.

See [?](#).

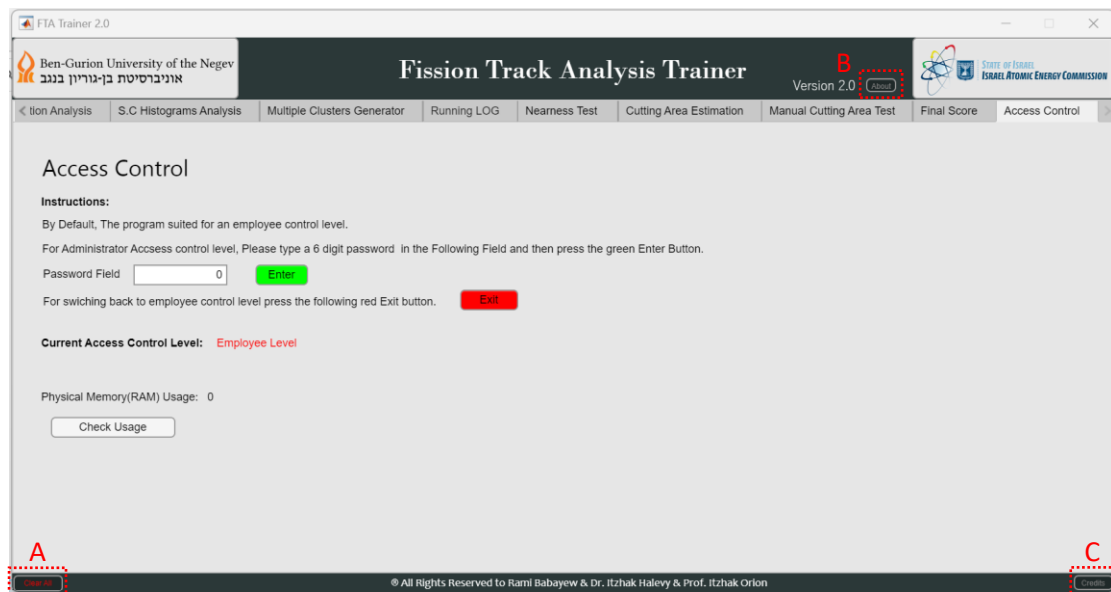


Figure 8. FTA Trainer General Buttons





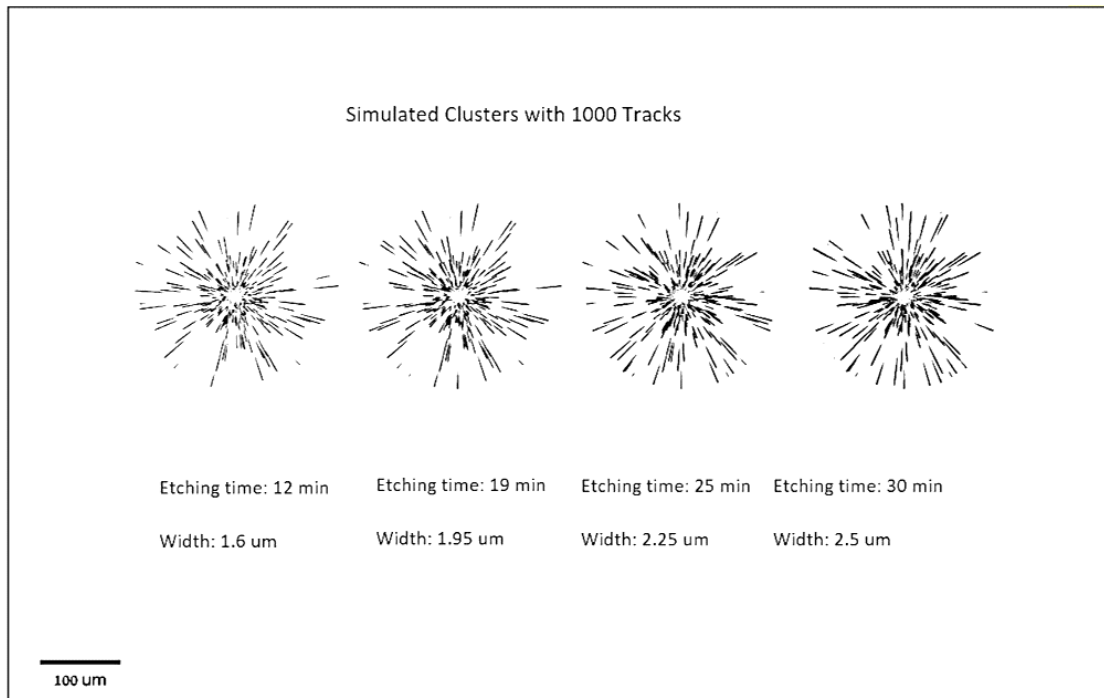
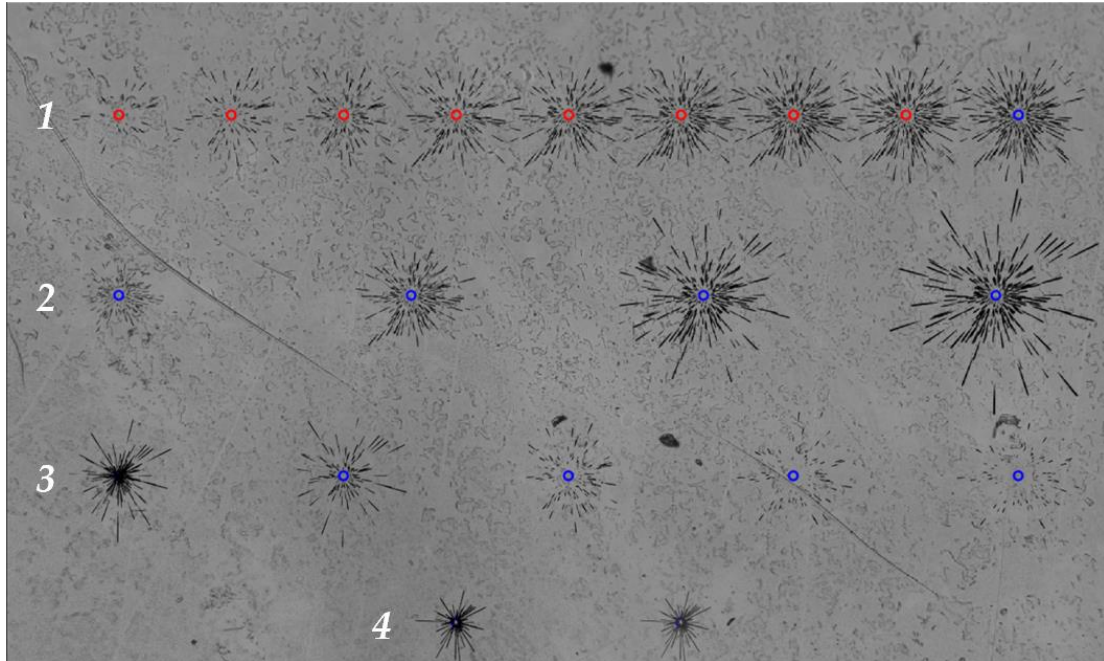
### 3. Using FTA Trainer Application

Detail the core features of your app and provide instructions on how to use them effectively.  
Break down complex features into sub-sections for clarity.

#### 3.1. Physical Parameters Tab

### 3.2. Single Clusters Generator Tab

Comparison Between Real and Simulated Single Clusters is shown in [?](#). The simulated clusters (Red centered) and the original single clusters look very resemble.



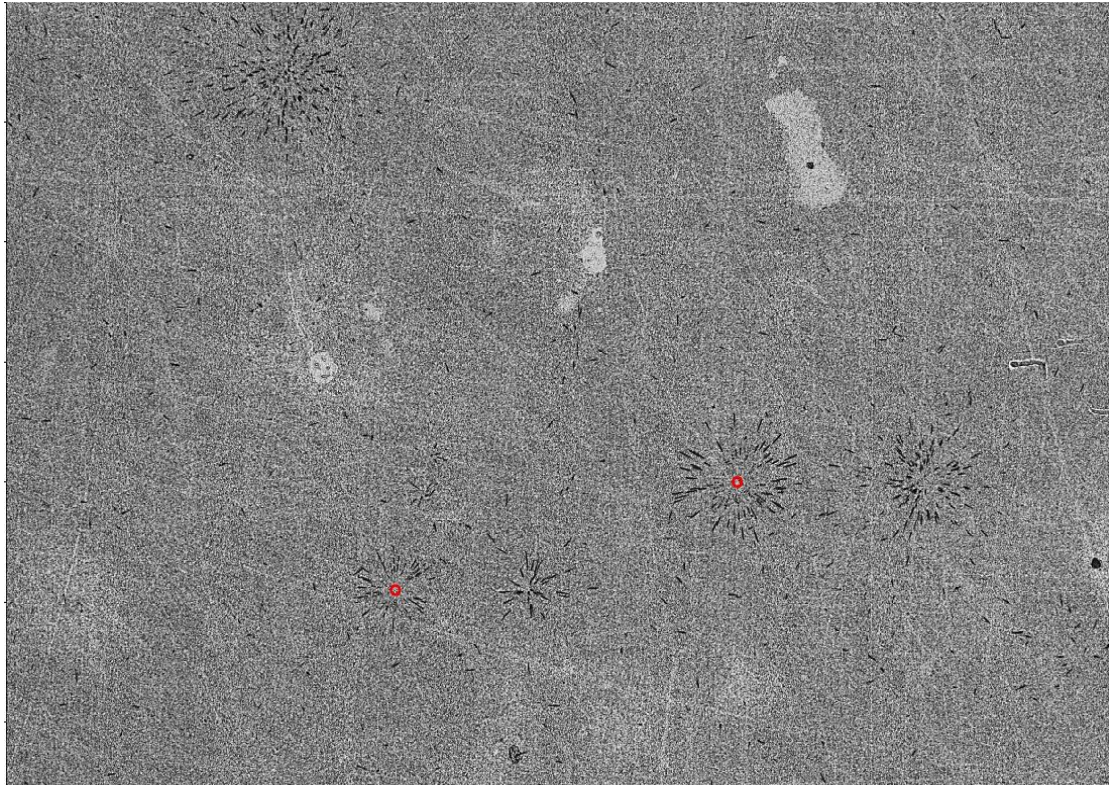


Figure 9. Comparison Between Real and Simulated (Red centered) Single Clusters



### 3.3. Graphical Axis Selection Tab

### 3.4. Single Clusters Projection Analysis

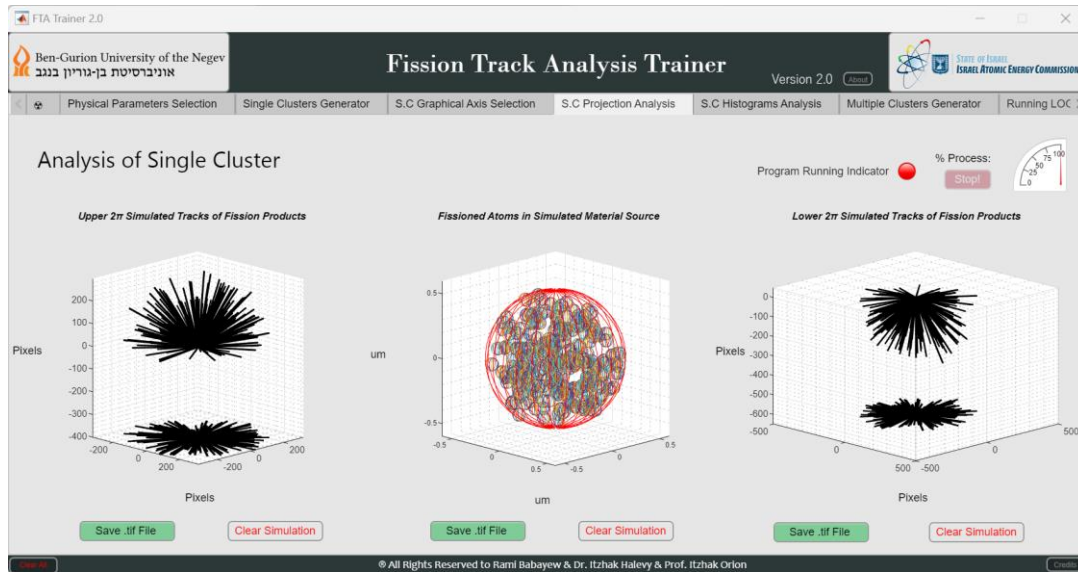


Figure 10. Projection Analysis Tab



### 3.5. Single Clusters Length Histogram Analysis

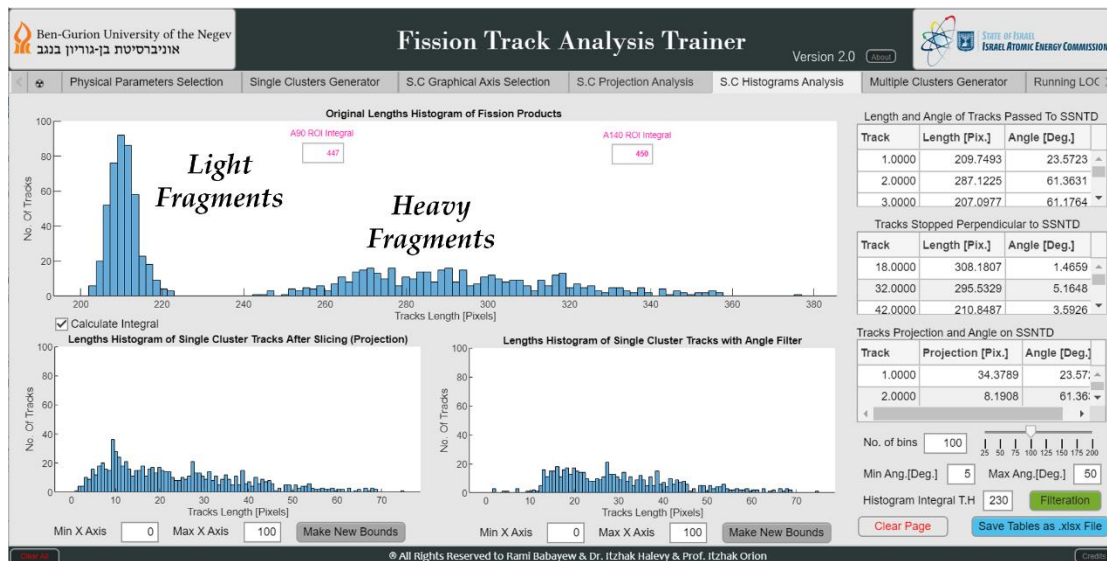
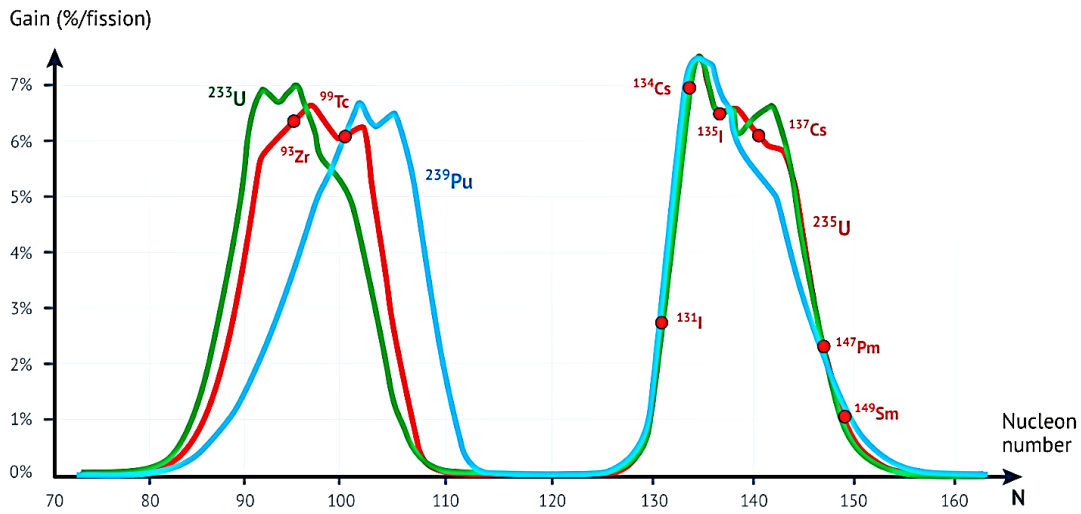


Figure 11. Fission Tracks Lengths Histogram Analysis Tab



### 3.6. Running LOG Tab

FIA Trainer 2.0

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Fission Track Analysis Trainer  
Version 2.0

Single Clusters Generator | S.C Graphical Axis Selection | S.C Projection Analysis | S.C Histograms Analysis | Multiple Clusters Generator | **Running LOG** | Nearness Test | Cutting Area Esti

Flux ...	Tracks	X Axis ...	Y Axis ...	Rad. ...	F.P Dia. [um]	Total Dia. [um]	Enri...	F.P Mass [pg]	F.P Vol. [um^3]	Total Vol [um^3]	Total Mass [pg]	Particle Depth[Pix.]	F	Isotope
5e+13	20	350	1944	1200	0.35514	1.8063	0.75	2.2324	0.18762	24.6874	293.7368	50	1..	U-235
5e+13	14	3716	1991	1200	0.31533	1.6727	0.67	1.5627	0.13134	19.6026	233.2388	50	1..	U-235
5e+13	37	552	2231	1200	0.43597	2.3242	0.66	4.1299	0.34711	52.5917	625.7424	50	1..	U-235
5e+13	36	3272	2096	1200	0.43201	2.2692	0.65	4.0183	0.33772	48.9455	582.3623	50	1..	U-235
5e+13	26	1878	1528	1200	0.3876	2.1213	0.61	2.9021	0.24391	39.9855	475.7541	50	1..	U-235
5e+13	26	3383	2198	1200	0.3876	1.9801	0.75	2.9021	0.24391	32.5216	386.9467	50	1..	U-235
5e+13	34	1139	691	1200	0.42385	2.1372	0.75	3.7951	0.31896	40.8925	486.5513	50	1..	U-235
5e+13	34	3216	953	1200	0.42385	2.1654	0.75	3.7951	0.31896	42.5282	506.0133	50	1..	U-235
5e+13	15	4046	1648	1200	0.32267	1.6949	0.69	1.6743	0.14072	20.394	242.6522	50	1..	U-235
5e+13	40	4079	430	1200	0.44745	2.2859	0.75	4.4648	0.37525	50.0332	595.3067	50	1..	U-235
5e+13	17	4278	845	1200	0.33641	1.7845	0.67	1.8975	0.15948	23.8031	283.209	50	1..	U-235
5e+13	18	1618	516	1200	0.34288	1.728	0.75	2.0092	0.16886	21.649	257.5897	50	1..	U-235
5e+13	40	465	279	1200	0.44745	2.3854	0.66	4.4648	0.37525	56.8559	676.4848	50	1..	U-235
5e+13	13	1893	1294	1200	0.30764	1.5679	0.77	1.4511	0.12196	15.8384	188.4545	50	1..	U-235
5e+13	14	1306	1088	1200	0.31533	1.6038	0.75	1.5627	0.13134	17.2812	205.6184	50	1..	U-235
5e+13	17	3801	1008	1200	0.33641	1.6891	0.75	1.8975	0.15948	20.1874	240.1899	50	1..	U-235
5e+13	39	734	1784	1200	0.44369	2.2872	0.73	4.3532	0.36587	50.1189	596.3288	50	1..	U-235
5e+13	31	2909	2623	1200	0.411	2.1911	0.66	3.4602	0.29082	44.0633	524.2727	50	1..	U-235

Enrichment [%]  Depleted <

Fissile Mass [pg]  Maximum Micro-Bulk Enrichment [%]  Mini-Bulk Enrichment [%]

Total Mass [pg]  Minimum Micro-Bulk Enrichment [%]  Standard Deviation [%]

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### 3.7. Multiple Clusters Generator Tab

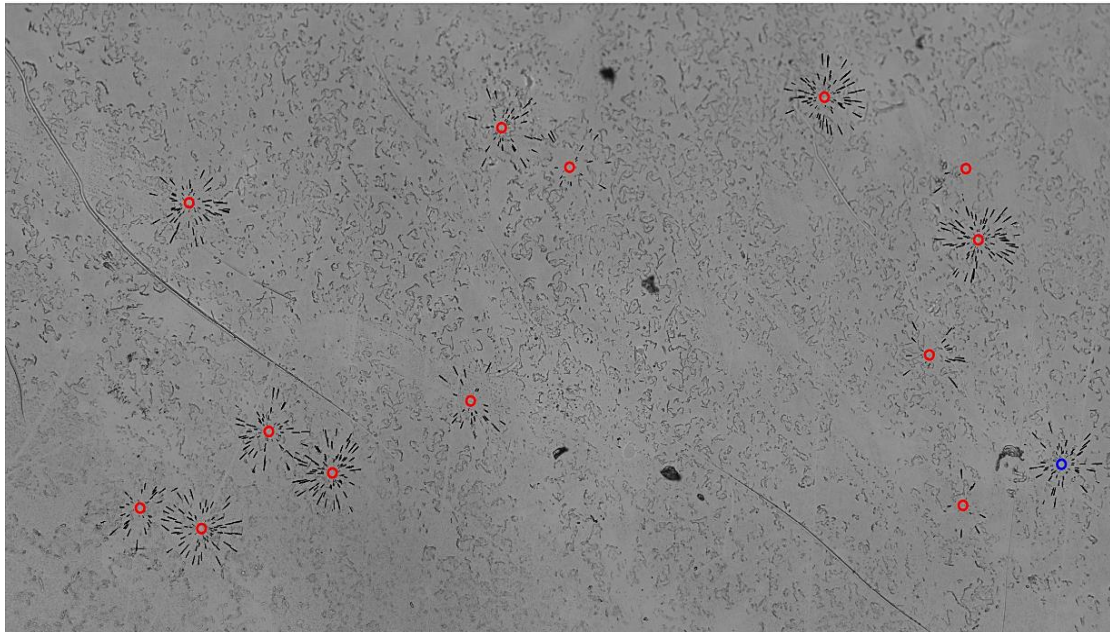
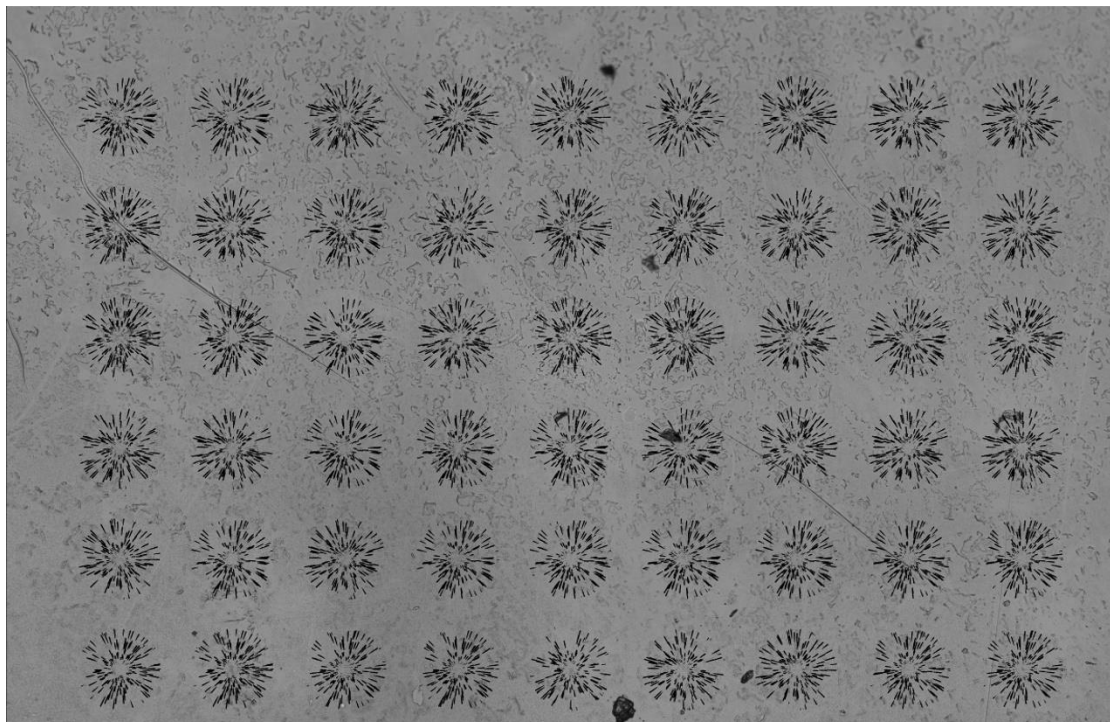
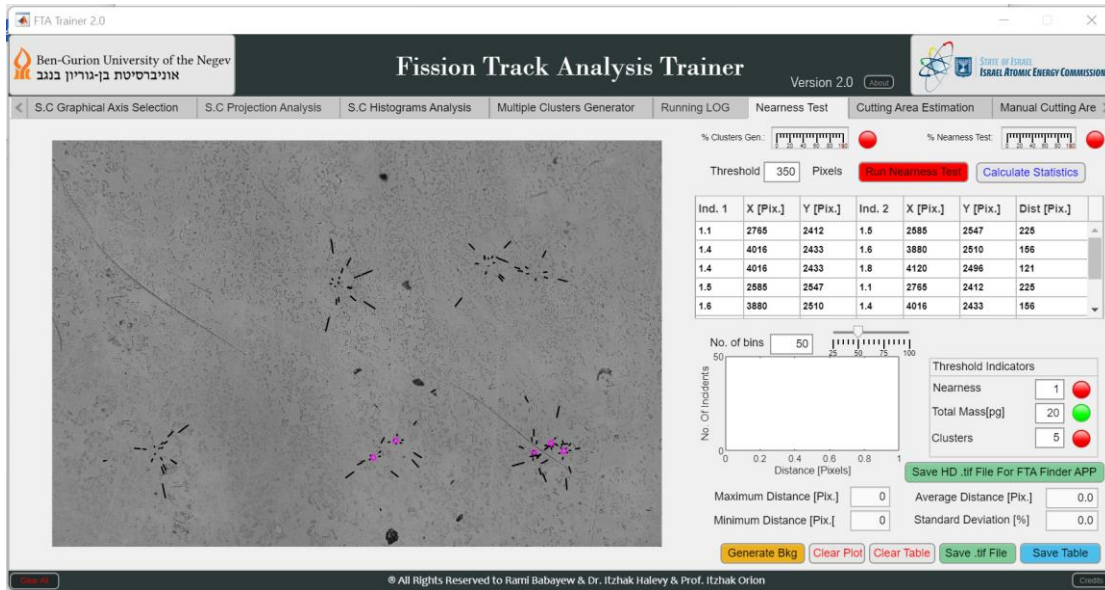


Figure 12. Generating Multiple Random Sized Clusters





### 3.8. Nearness Test Tab



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Ben-Gurion University of the Negev  
אוניברסיטת בן-גוריון בנגב

Fission Track Analysis Trainer

Version 2.0

S.C Graphical Axis Selection | S.C Projection Analysis | S.C Histograms Analysis | Multiple Clusters Generator | Running LOG | **Nearness Test** | Cutting Area Estimation | Manual Cutting Area

% Clusters Gen: [Progress Bar] % Nearness Test: [Progress Bar]

Threshold: 350 Pixels **Run Nearness Test** Calculate Statistics

Ind. 1	X [Pix.]	Y [Pix.]	Ind. 2	X [Pix.]	Y [Pix.]	Dist [Pix.]
1.1	2765	2412	1.5	2585	2547	225
1.4	4016	2433	1.6	3880	2510	156
1.4	4016	2433	1.8	4120	2496	121
1.5	2585	2547	1.1	2765	2412	225
1.6	3880	2510	1.4	4016	2433	156

No. of bins: 50

No. of Incidents vs. Distance [Pixels] (Histogram)

Threshold Indicators:  
 Nearness: 1 (Red)  
 Total Mass[pg]: 20 (Green)  
 Clusters: 5 (Red)

Save HD .tif File For FTA Finder APP

Maximum Distance [Pix.]: 0 Average Distance [Pix.]: 0.0  
 Minimum Distance [Pix.]: 0 Standard Deviation [%]: 0.0

Generate Bkg Clear Plot Clear Table Save .tif File Save Table

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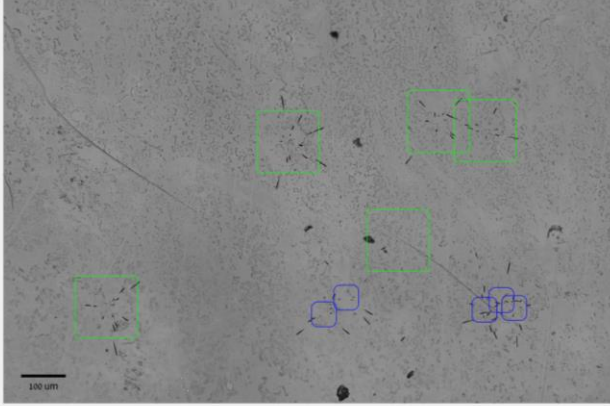
### 3.9. Cutting Area Estimation Tab

FTA Trainer 2.0

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Threshold: 350 Pixels

Run Number	X Axis [Pix.]	Y Axis [Pix.]	Pass Nearness?
1.1	2765	2412	No
1.2	831	2488	Yes
1.3	3510	994	Yes
1.4	4016	2433	No
1.5	2585	2547	No
1.6	3880	2510	No
1.7	3183	1952	Yes
1.8	4120	2496	No
1.9	3885	1069	Yes
1.10	2297	1157	Yes

Enable Estimation Again

Pass Rectangle X-Y Length [Pix]   
 Fall Rectangle X-Y Length [Pix]

Save HD .tif File For FTA Finder APP

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### 3.10. Manual Cutting Area Tab

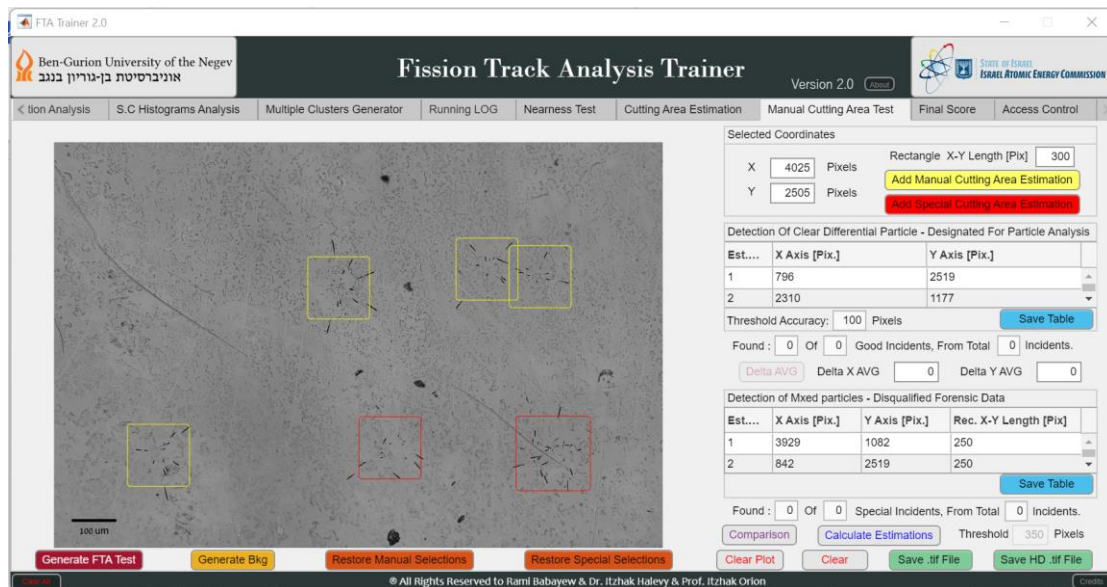


Figure 13. Manuel Cutting Area Test in progress

After the test is completed, it's possible to compare between the selected areas to the generated rectangles visually. The comparison gives an option to the user to do a reflection on his own abilities. [See?](#)

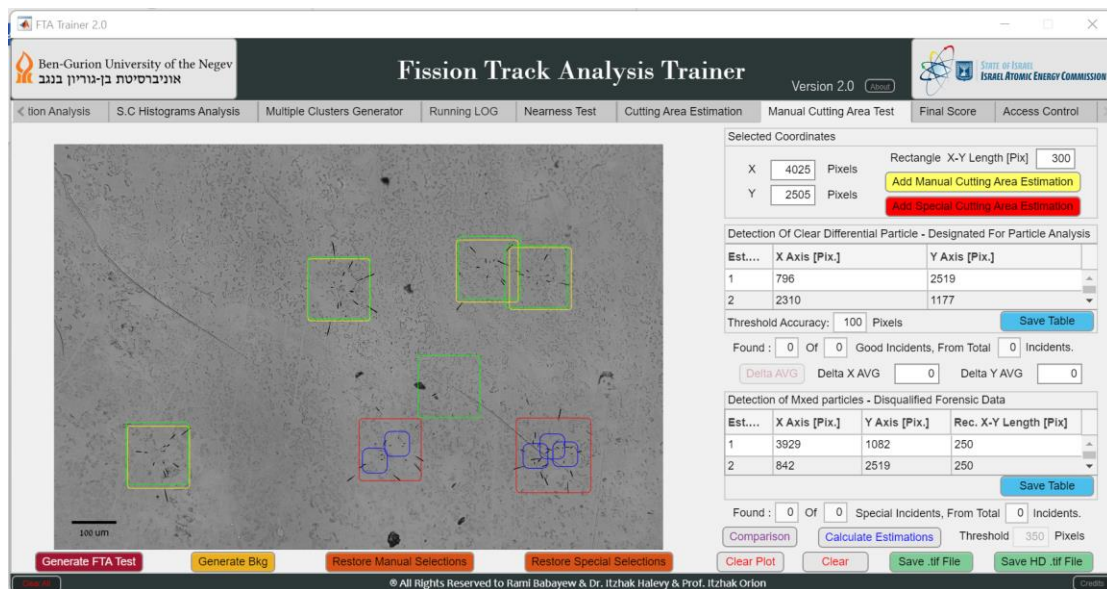


Figure 14. Cutting Area Estimation Tab



### 3.11. Finale Score Tab



### 3.12. Access Control



## 4. Settings and Preferences

Explain how users can customize their app settings and preferences to tailor the experience to their liking.



## 5. Troubleshooting

Offer guidance on how to resolve common issues and provide answers to frequently asked questions.



## 6. Security and Privacy

Highlight the security measures in place to protect user data and explain how users can manage their privacy settings.



## 7. Updates and Maintenance

Inform users about how to keep their app up-to-date and provide maintenance tips for optimal performance.



## 8. Legal Information

Include links to your app's terms of service, privacy policy, and any relevant licensing information.



## 9. Feedback and Suggestions

Encourage users to provide feedback and suggest new features, and explain how they can do so.



## 10. Conclusion

Wrap up the user guide with a thank-you message and any additional information you want to convey.