



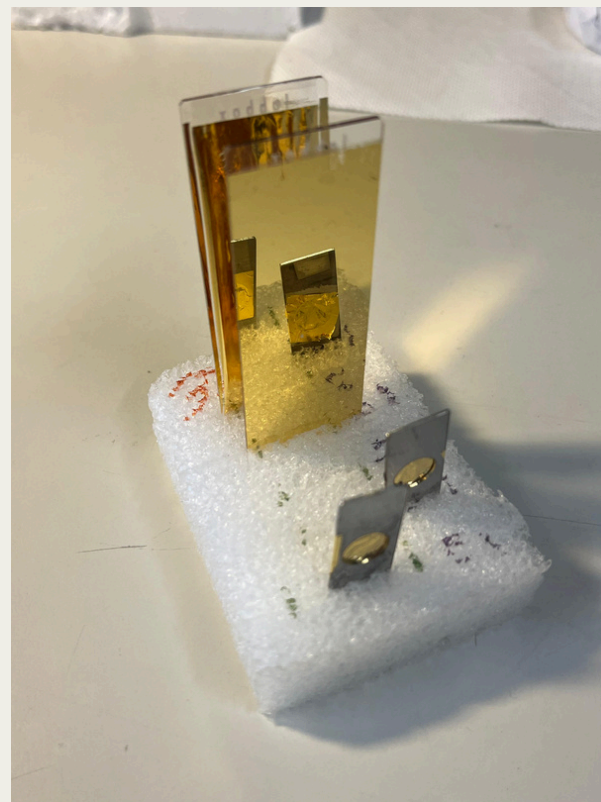
ARC-TF: A GUI FOR THIN FILM CHARACTERIZATION

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CONTEXT

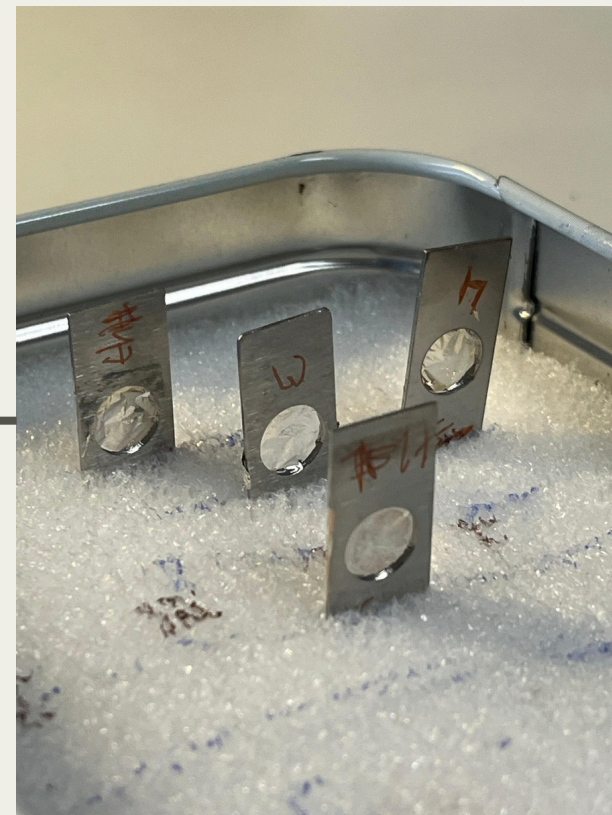
Thin Films



Gold targets

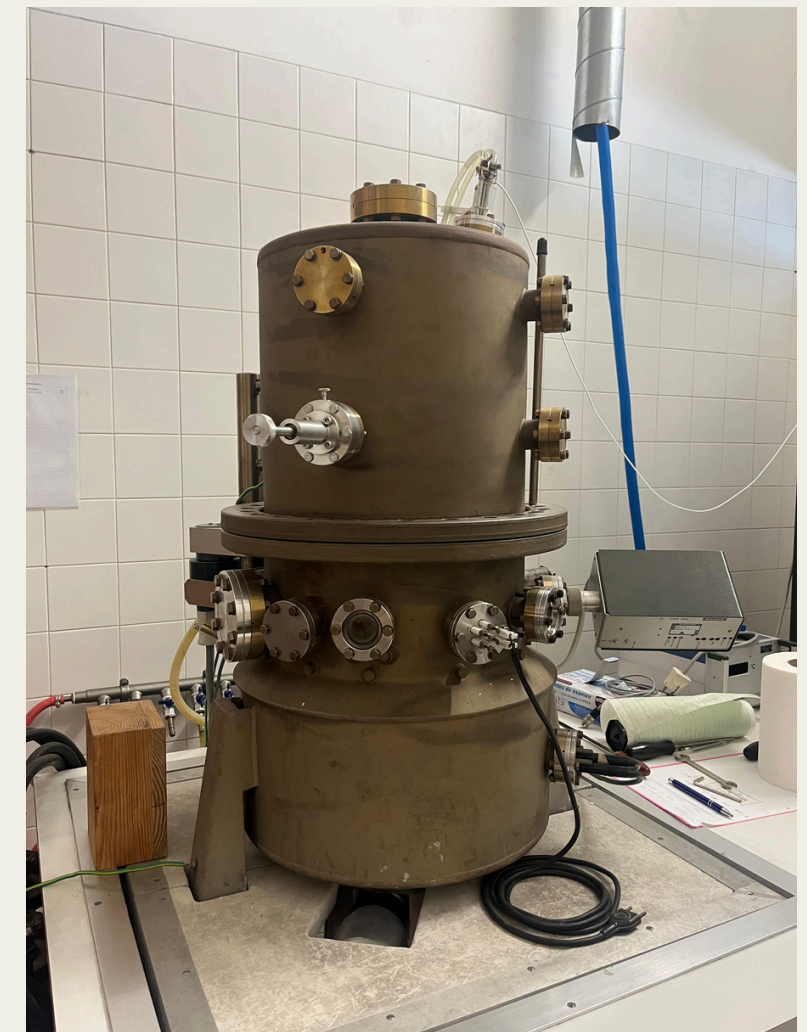


Sn, Formvar, Pb,
Au targets



Ag targets

Physical Vapor Deposition chamber



CHARACTERIZATION

Alpha Energy Loss

- measures thickness and uniformity
- risk of damaging films due to vacuum



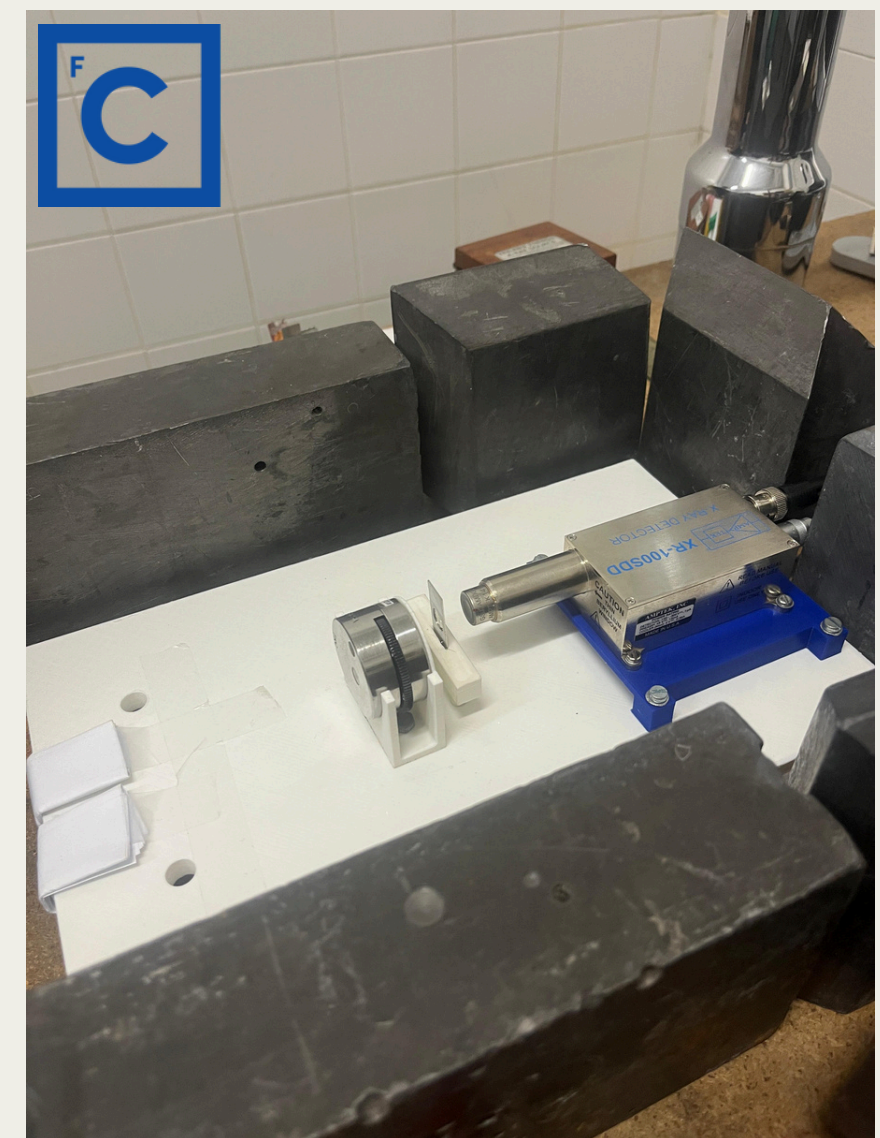
Rutherford Backscattering Spectrometry

- measures thickness, uniformity and impurities
- requires beam time request/vacuum



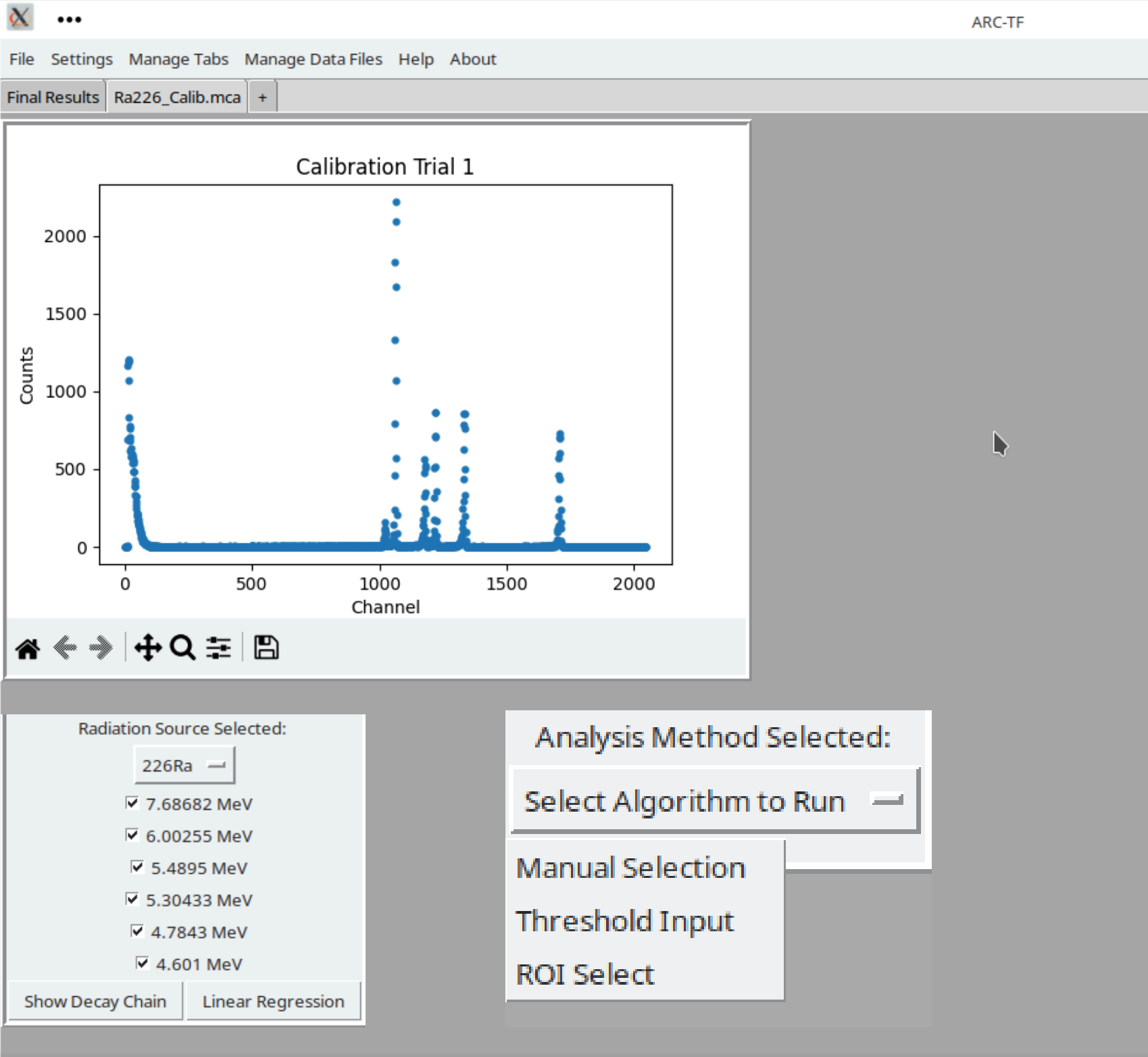
X-Ray Attenuation

- measures thickness
- Filippa already talked about it



GOAL: IMPLEMENT XRA IN INTERFACE

Initially :



- Alpha Energy Loss technique was implemented
- LIP Internships 2023
- To expedite the film analysis
- Analysing 1 film: ~10 min → 1 min

LIP-STUDENTS-23-15

Developing a GUI for thin film characterization

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Abstract. An article describing the methodology, workflow, creation and methods of a Graphic User Interface (GUI) that facilitates the characterization of thin films, using the Alpha Energy Loss method. This GUI was created in Python, using the Tkinter library. The calculations are based on the procedures used by the NUC-RIA team to obtain the thickness of a film, and are shown in this article. Simple algorithms were developed to detect the peaks of the energy loss data and will likewise be addressed.

KEYWORDS: Thin Films, Characterization, AEL, Python, Tkinter

1 Introduction

The one thing all fundamental nuclear reaction studies and production of radioactive beams have in common is that the approximated thickness of the film, in the background of the GUI, as equation 2 is very easily implemented in code. A full description of the analysis performed by the NUC-RIA group follows:

X-RAY ATTENUATION ANALYSIS

Beer-Lambert Law:

Linear Attenuation coefficient x - thickness of material

$$I = I_0 \cdot e^{-\mu \cdot x}$$

Attenuated Intensity Unattenuated Intensity

To find the film thickness:

$$x = -\frac{1}{\mu} \ln\left(\frac{I}{I_0}\right)$$

μ - from NIST website

← → ↻ <https://physics.nist.gov/cgi-bin/Xcom/Xcom2?Method=Elem&Output2=Hand>

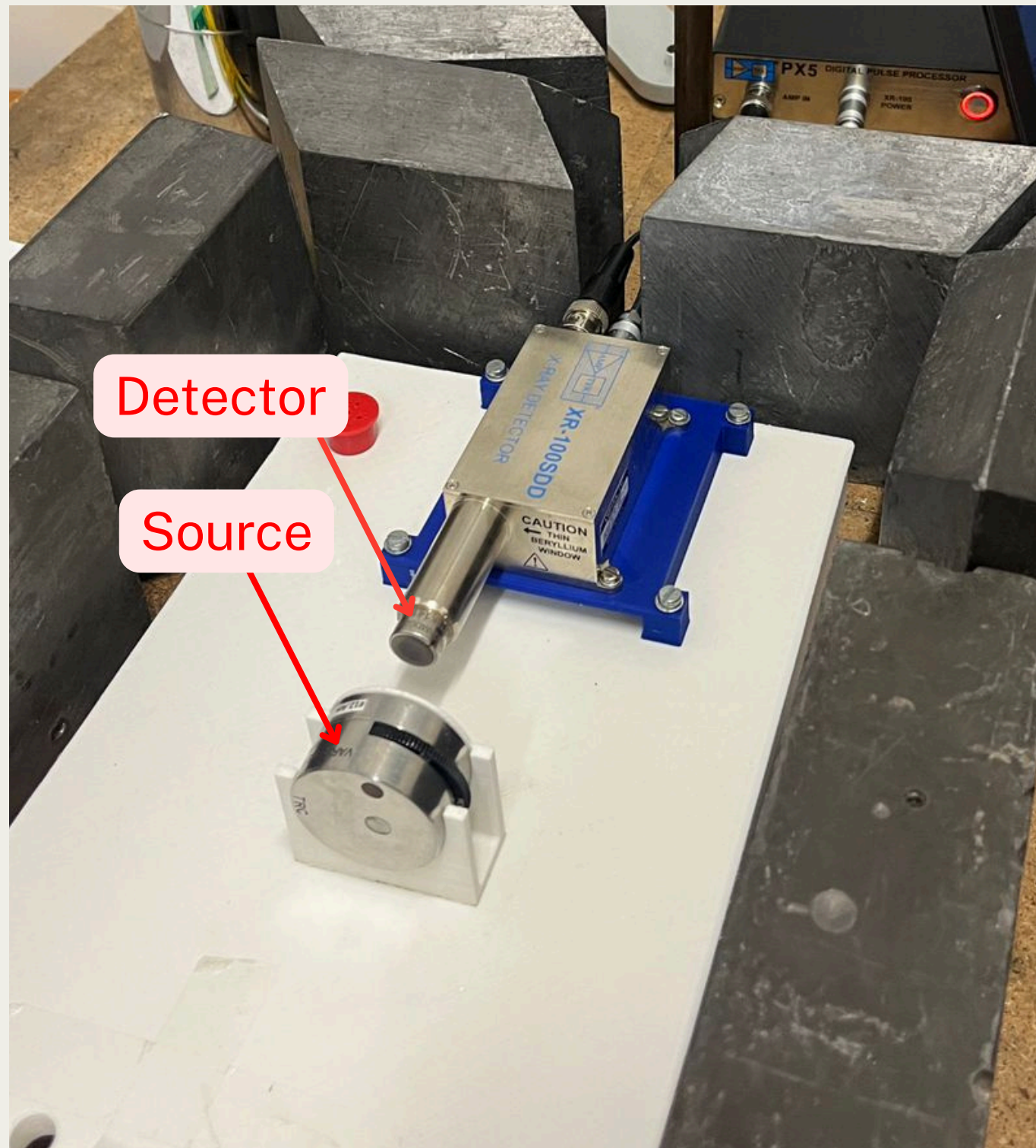
Fill out the form to select the data to be displayed:

[Help](#)

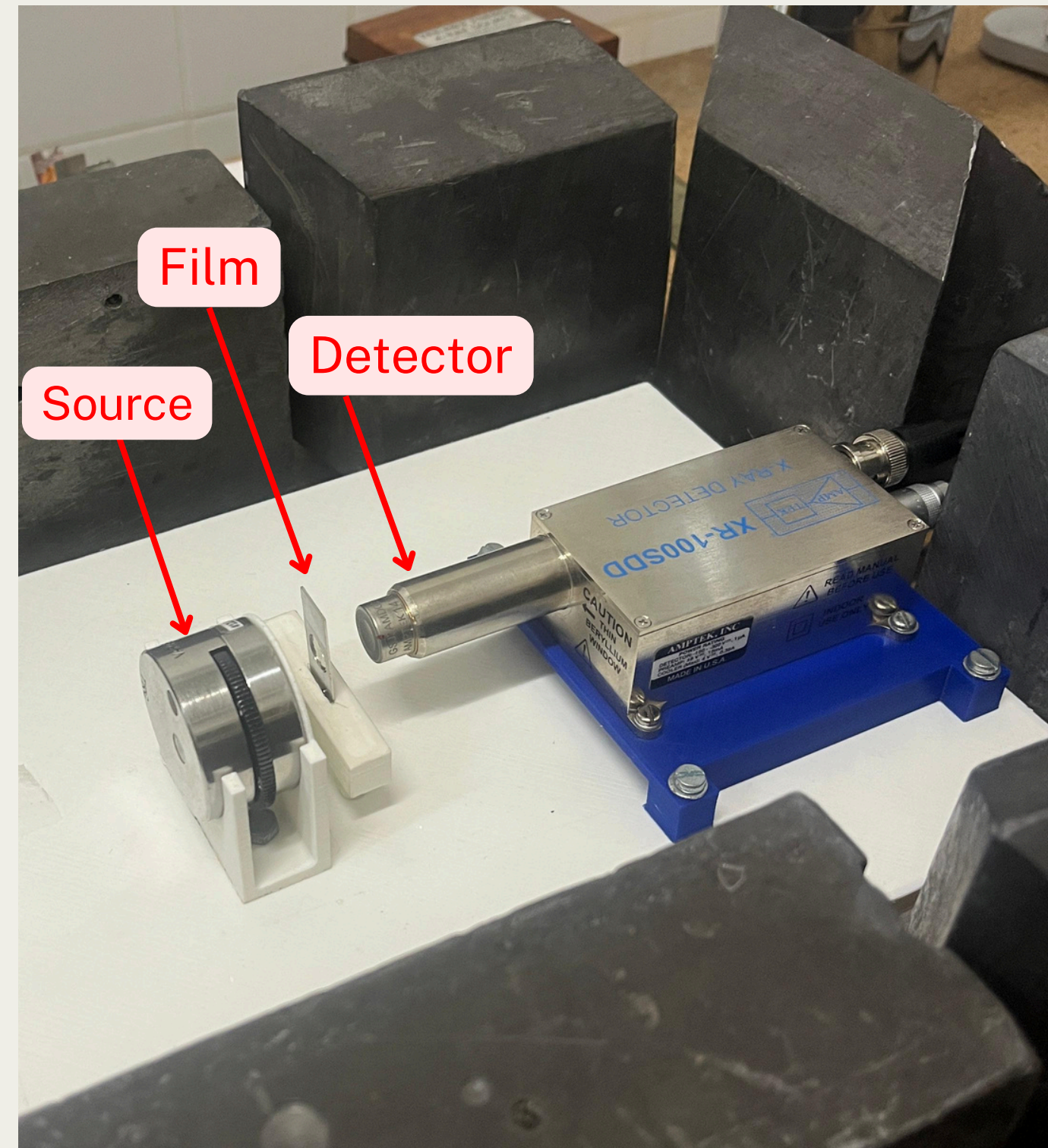
Select by: (only elements 1 - 100) Atomic Number: <input type="text"/> or Symbol: <input type="text" value="Au"/>	Options for output units: <input checked="" type="radio"/> All quantities in cm^2/g <input type="radio"/> All quantities in barns/atom <input type="radio"/> Partial interaction coefficients in barns/atom and total attenuation coefficients in cm^2/g
Graph options: <input checked="" type="checkbox"/> Total Attenuation with Coherent Scattering <input type="checkbox"/> Total Attenuation without Coherent Scattering <input type="checkbox"/> Coherent Scattering <input type="checkbox"/> Incoherent Scattering <input type="checkbox"/> Photoelectric Absorption <input type="checkbox"/> Pair Production in Nuclear Field <input type="checkbox"/> Pair Production in Electron Field <input type="checkbox"/> None	Additional energies in MeV: (optional) (up to 100 allowed) Note: Energies must be between 0.001 - 100000 MeV (1 keV - 100 GeV) (only 4 significant figures will be used). One energy per line. Blank lines will be ignored. <input type="text" value="0.006042"/> <input type="checkbox"/> Include the standard grid Energy Range: Minimum: <input type="text" value="0.001"/> MeV Maximum: <input type="text" value="100000"/> MeV

X-RAY ATTENUATION ANALYSIS

Without film:

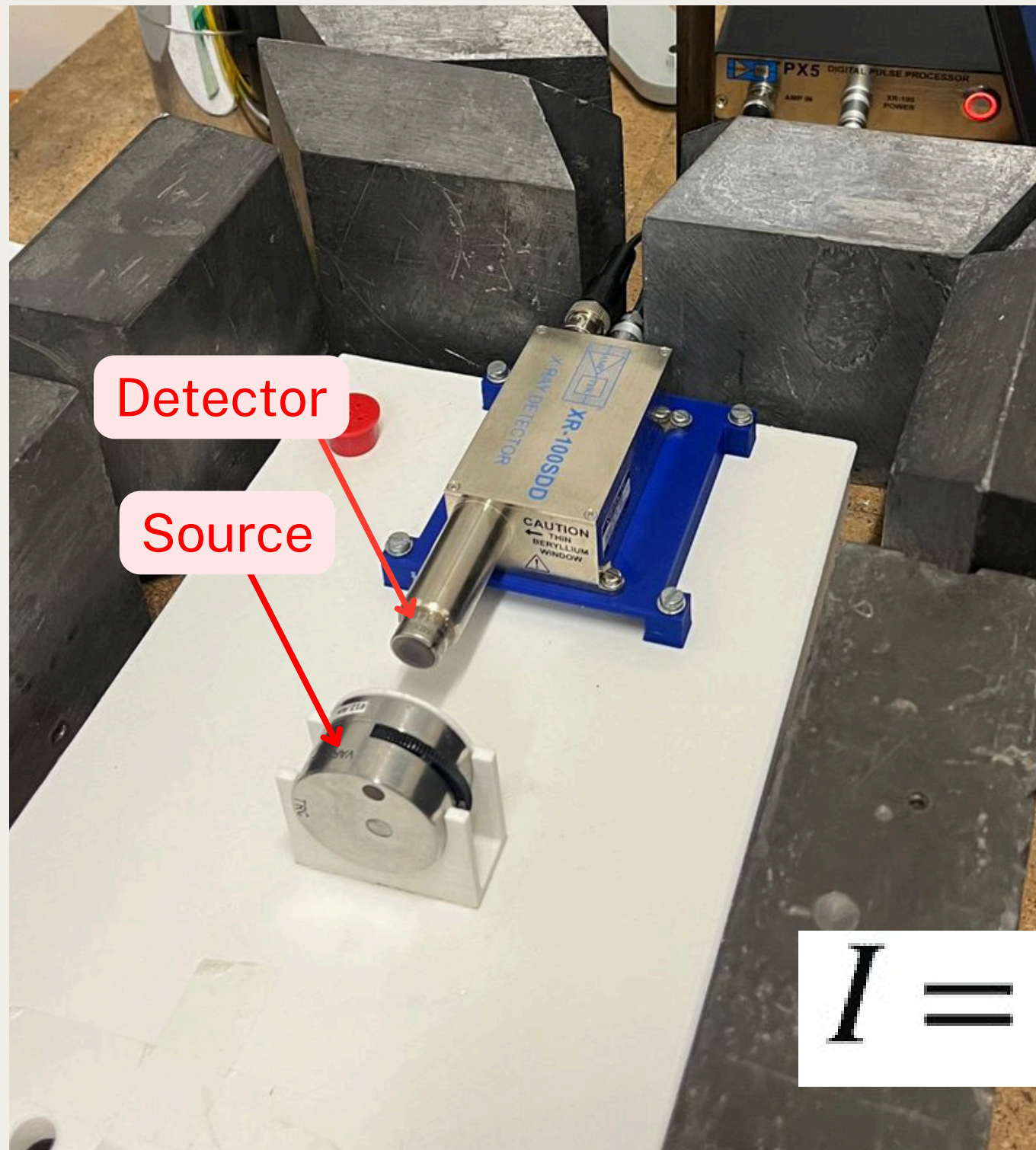


With film:

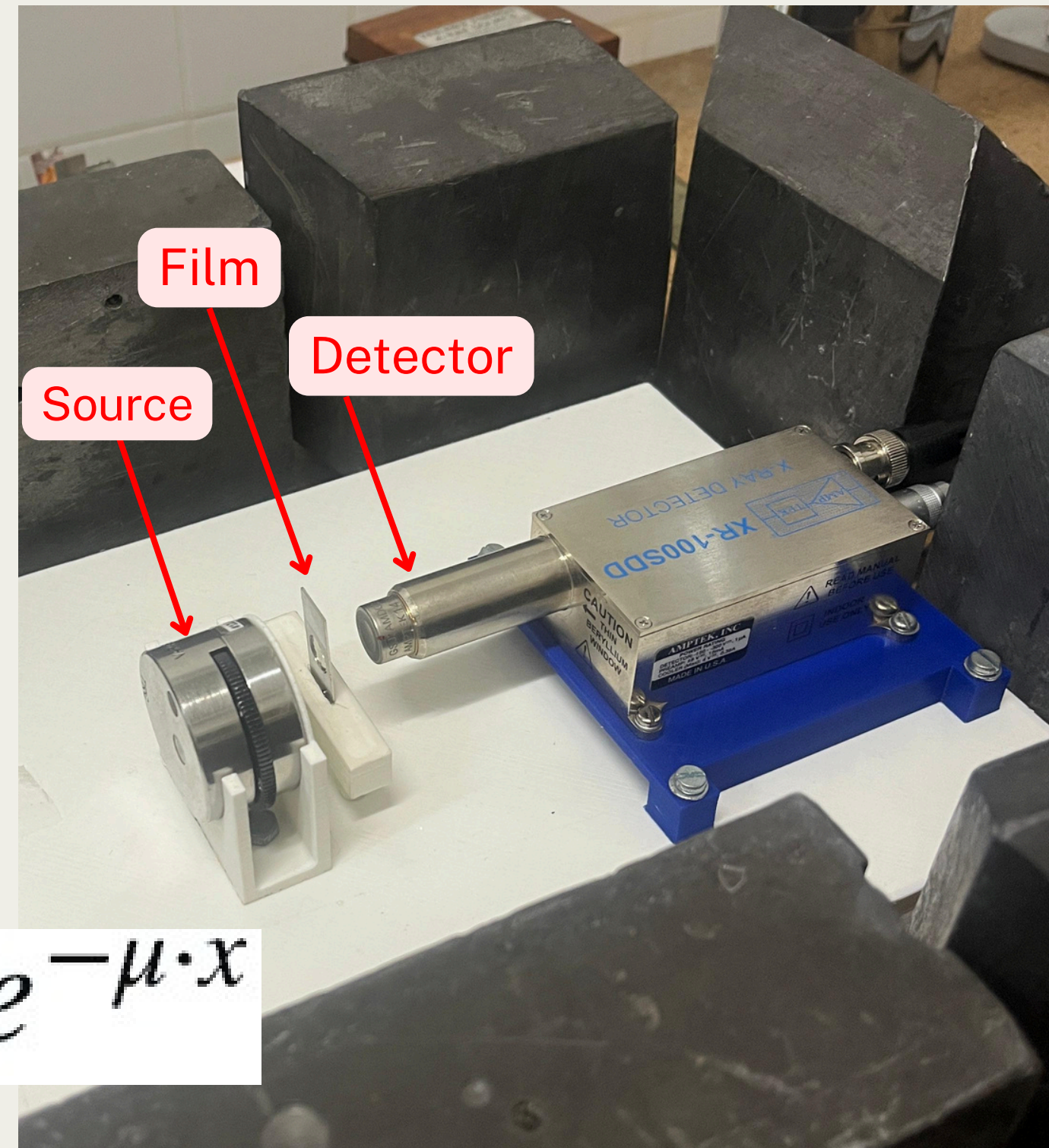


X-RAY ATTENUATION ANALYSIS

Without film:



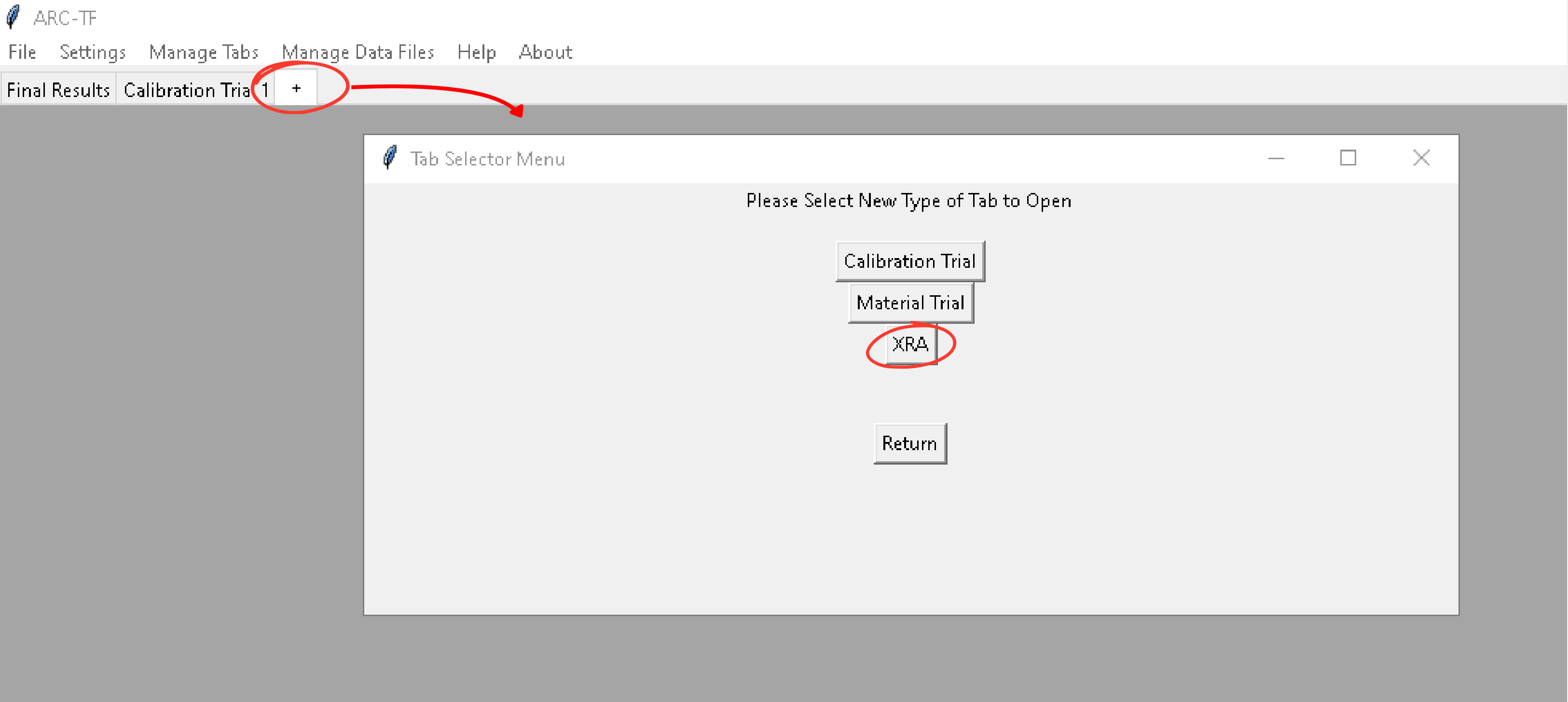
With film:



$$I = I_0 \cdot e^{-\mu \cdot x}$$

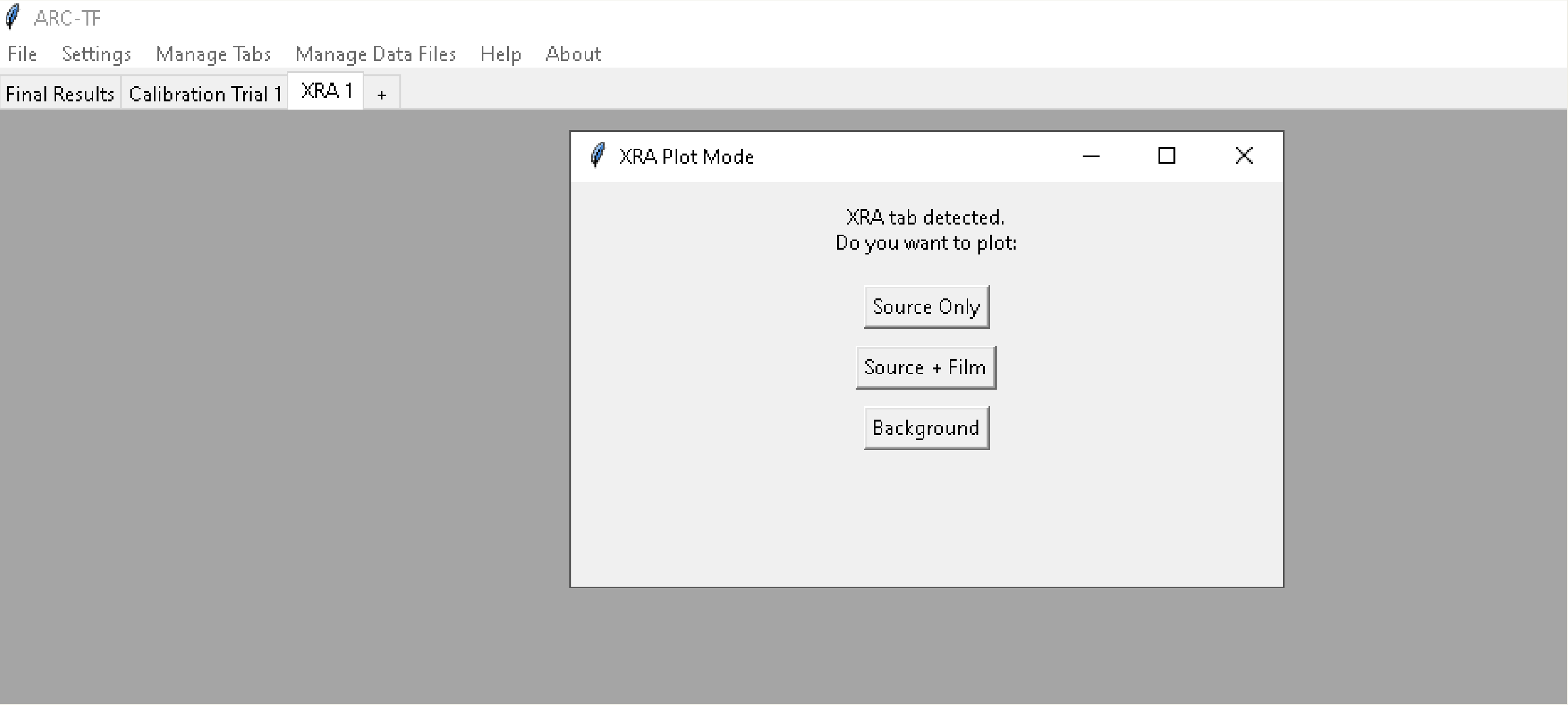
XRA WORKFLOW

New features added:
Tab Selector Menu:



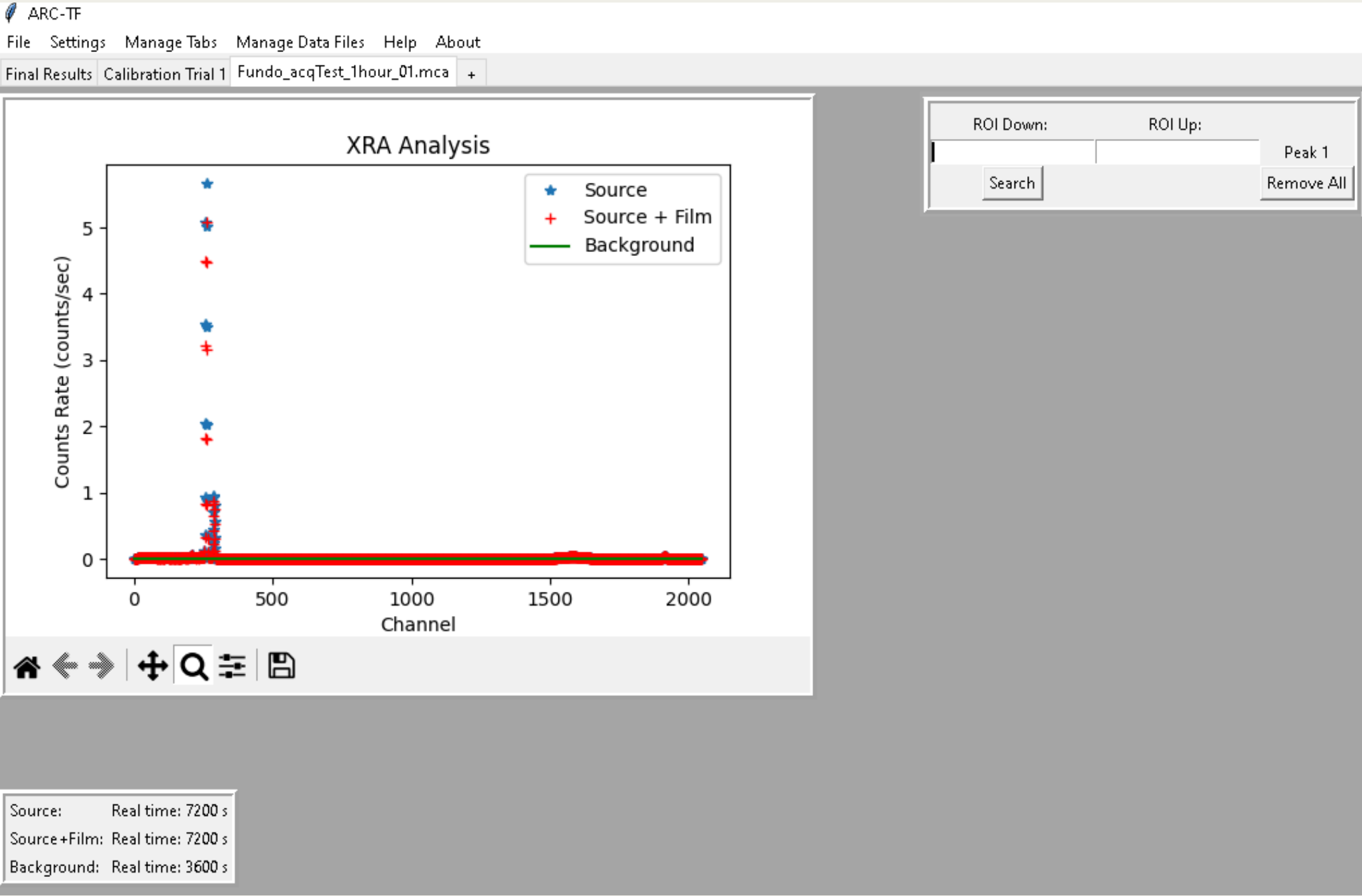
XRA WORKFLOW

New features added: Plot Data Menu:



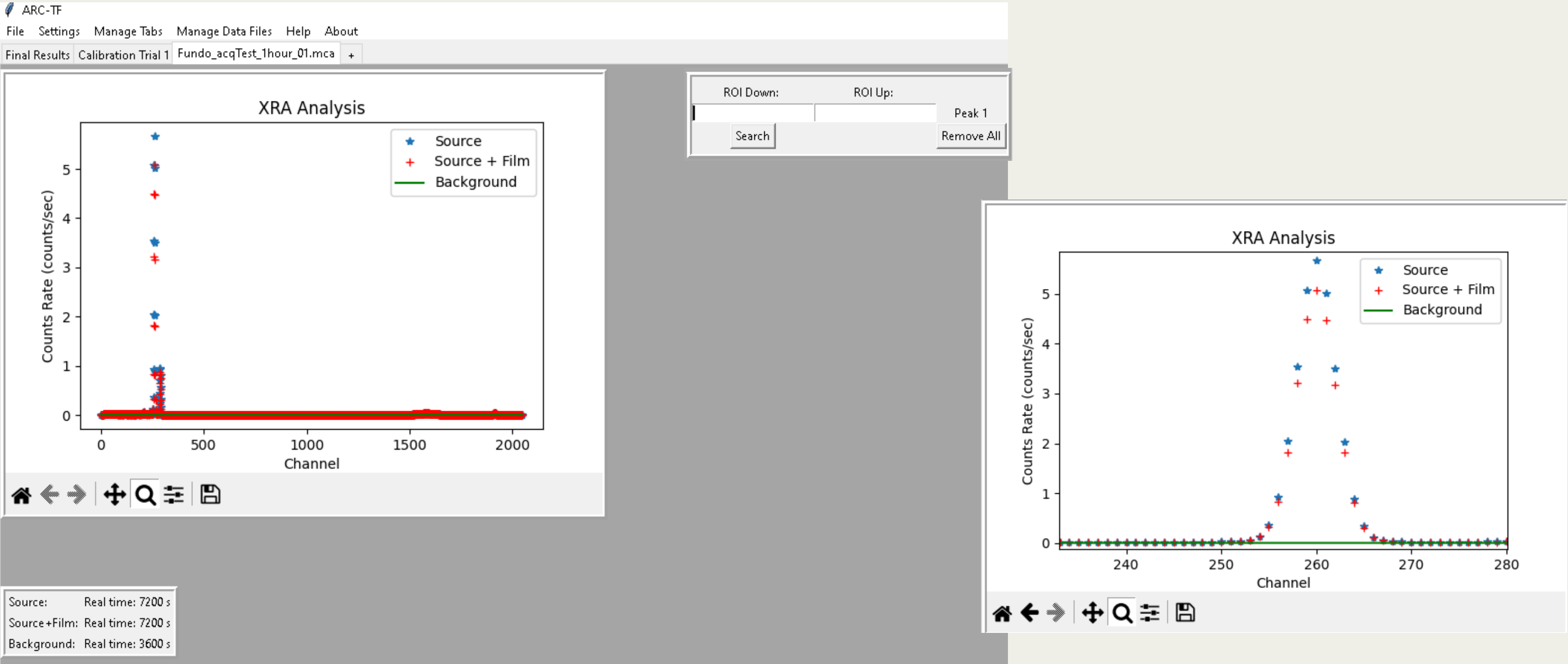
XRA WORKFLOW

New features added:
Algorithm Frame:



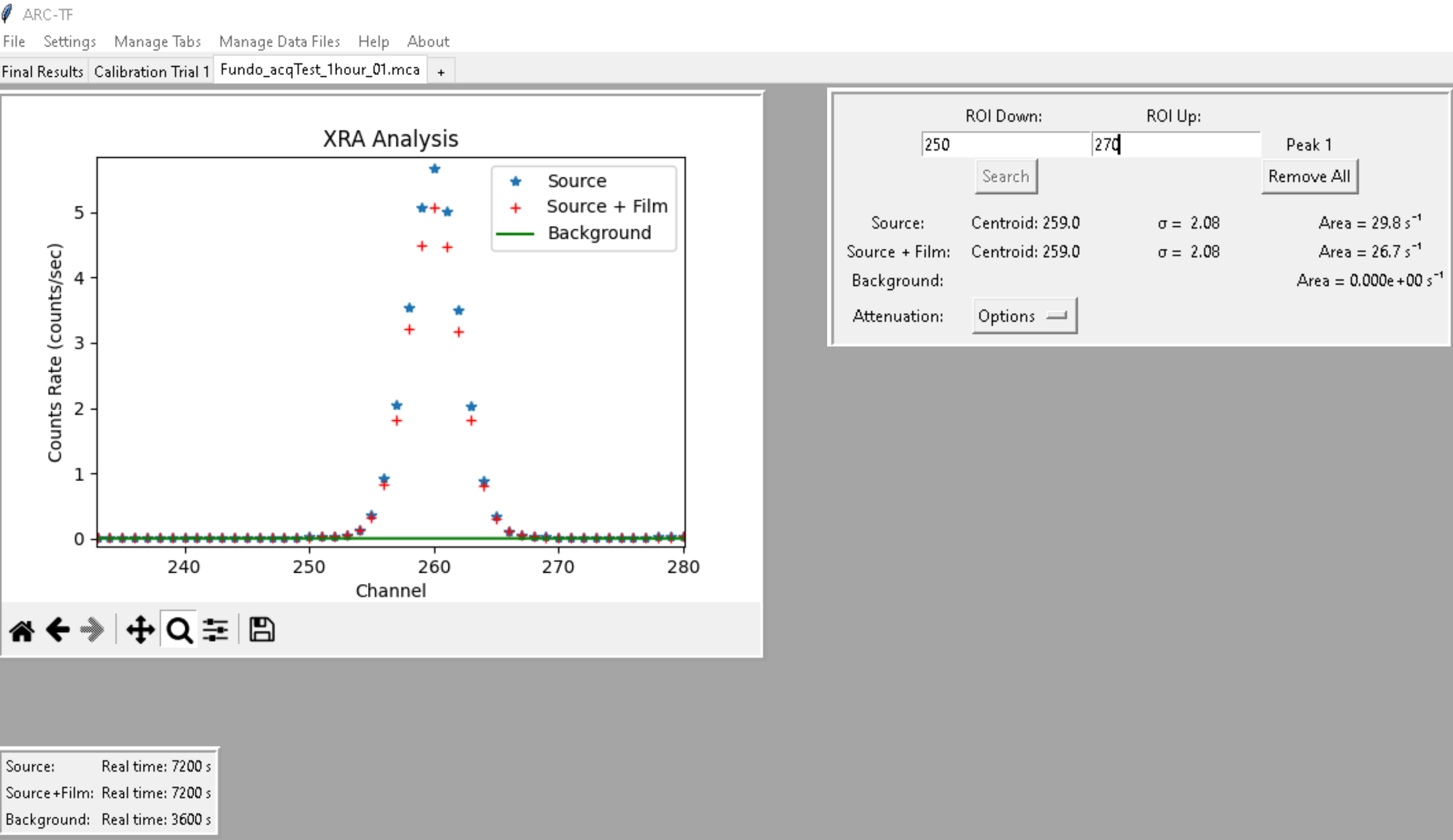
XRA WORKFLOW

New features added:
Algorithm Frame:



XRA WORKFLOW

New features added: Algorithm Frame:



XRA WORKFLOW

New features added: Algorithm Frame:

ROI Down:250ROI Up:270Peak 1

SearchRemove All

Source:Centroid: 259.0σ = 2.08Area = 29.8 s⁻¹

Source + Film:Centroid: 259.0σ = 2.08Area = 26.7 s⁻¹

Background:Area = 0.000e+00 s⁻¹

Attenuation:Options

DefaultUser

User chooses attenuation coefficient method

ROI Down:250ROI Up:270Peak 1

SearchRemove All

Source:Centroid: 259.0σ = 2.08Area = 29.8 s⁻¹

Source + Film:Centroid: 259.0σ = 2.08Area = 26.7 s⁻¹

Background:Area = 0.000e+00 s⁻¹

Attenuation:Default

FilmsSources

Run

SnAgAlAuPb

User chooses the film material

ROI Down:250ROI Up:270Peak 1

SearchRemove All

Source:Centroid: 259.0σ = 2.08Area = 29.8 s⁻¹

Source + Film:Centroid: 259.0σ = 2.08Area = 26.7 s⁻¹

Background:Area = 0.000e+00 s⁻¹

Attenuation:Default

FilmsSources

Run

Cu Kα — 8.041 keV
Ag Kα — 22.103 keV
Ba Kα — 32.061 keV
Mo Kα — 17.443 keV
Rb Kα — 13.376 keV
Tb Kα — 44.218 keV

User chooses the source material

XRA WORKFLOW

New features added:
Algorithm Frame:

ROI Down:

250

ROI Up:

270

Peak 1

Search

Remove All

Source:	Centroid: 259.0	$\sigma = 2.08$	Area = 29.8 s ⁻¹
Source + Film:	Centroid: 259.0	$\sigma = 2.08$	Area = 26.7 s ⁻¹
Background:			Area = 0.000e+00 s ⁻¹

Attenuation:

Default

Sn

Cu K α — 8.041 keV

Run

$\mu = 1805.570 \text{ cm}^{-1}$
Thickness = (609 ± 17) nm

XRA WORKFLOW

New features added: Algorithm Frame:

ROI Down: 250

ROI Up: 270

Peak 1

Search

Remove All

Source:

Source + Film:

Background:

Attenuation:

Centroid: 259.0

Centroid: 259.0

$\sigma = 2.08$

$\sigma = 2.08$

Area = 29.8 s⁻¹

Area = 26.7 s⁻¹

Area = 0.000e+00 s⁻¹

User

Enter the linear attenuation coefficient in cm⁻¹:

Run

ROI Down: 250

ROI Up: 270

Peak 1

Search

Remove All

Source:

Source + Film:

Background:

Attenuation:

Centroid: 259.0

Centroid: 259.0

$\sigma = 2.08$

$\sigma = 2.08$

Area = 29.8 s⁻¹

Area = 26.7 s⁻¹

Area = 0.000e+00 s⁻¹

User

Enter the linear attenuation coefficient in cm⁻¹: 1805

Run

$\mu = 1805.000 \text{ cm}^{-1}$

Thickness = (609 ± 17) nm

RESULTS

- Household Al foil



	ROI Down:	ROI Up:	
	250	270	Peak 1
	<input type="button" value="Search"/>		<input type="button" value="Remove All"/>
Source:	Centroid: 259.0	$\sigma = 2.10$	Area = 30.0 s^{-1}
Source + Film:	Centroid: 259.0	$\sigma = 2.09$	Area = 25.2 s^{-1}
Attenuation:	<input type="button" value="Default"/>		
	<input type="button" value="Al"/>	<input type="button" value="Cu K<math>\alpha</math> — 8.041 keV"/>	<input type="button" value="Run"/>
			$\mu = 133.920 \text{ cm}^{-1}$
			Thickness = $(12.9 \pm 0.5) \text{ }\mu\text{m}$

Typical value for household Al foil.

RESULTS

- Au film

Using Alpha Energy Loss technique:

Material of Film Used:

Choose the Calibration Regression
Make sure the Peaks in the Calibration match the Peaks found for this trial

Thickness (nm)	Channel
188.34	576
182.85	618
209.44	686
189.30	742
166.56	968

Average Thickness (nm) Uncertainty (nm)

Using X-Ray Attenuation analysis:

ROI Down: ROI Up:

Source: Centroid: 258.9 $\sigma = 2.10$ Area = 29.4 s^{-1}

Source + Film: Centroid: 259.0 $\sigma = 2.09$ Area = 27.6 s^{-1}

Attenuation:

$\mu = 3952.810 \text{ cm}^{-1}$

Thickness = $(163 \pm 11) \text{ nm}$

AEL: $(187 \pm 15) \text{ nm}$

XRA: $(163 \pm 11) \text{ nm}$



RESULTS

- Pb film

Using Alpha Energy Loss technique:

Material of Film Used:

Choose the Calibration Regression
Make sure the Peaks in the Calibration match the Peaks found for this trial

Thickness (nm)	Channel
1938.20	474
1944.03	535
1932.44	557
1994.24	615
1981.44	810

Average Thickness (nm) Uncertainty (nm)

Using X-Ray Attenuation analysis:

ROI Down: ROI Up:

Source: Centroid: 259.0 $\sigma = 2.08$ Area = 21.2 s⁻¹

Source + Film: Centroid: 259.0 $\sigma = 2.08$ Area = 12.8 s⁻¹

Attenuation:

$\mu = 2562.840 \text{ cm}^{-1}$

Thickness = (1.96 \pm 0.02) μm

AEL: (1.96 \pm 0.03) μm

XRA: (1.96 \pm 0.02) μm



CONCLUSION

- **Objective achieved:** XRA method integrated into interface
- **Future perspectives:** New features could be implemented

Acquired skills:

- Learned and Developed Python skills
- GUI development using Python (Tkinter library)
- Git and GitHub basic skills
- Knowledge on Radioactive Sources
- Knowledge on Thin Film Technology, Application and Production



Thank you!

ARC-TF at: https://github.com/RiPires/GUI_thin_films.git



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