Contamination analysis with InterSpec

https://sandialabs.github.io/InterSpec/
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Download, tutorials, code: https://sandialabs.github.io/InterSpec

Feature requests, bugs, support: email InterSpec@sandia.gov

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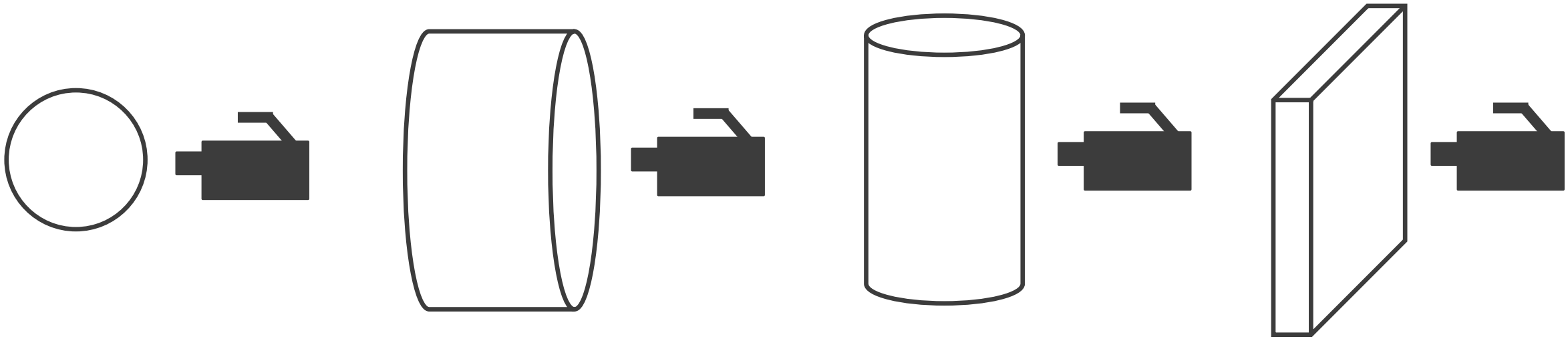
InterSpec for soil and other contamination analysis

InterSpec supports determining contamination
via adding trace sources to a shielding



Spherical

End-on Cylinder

Side-on Cylinder

Rectangular

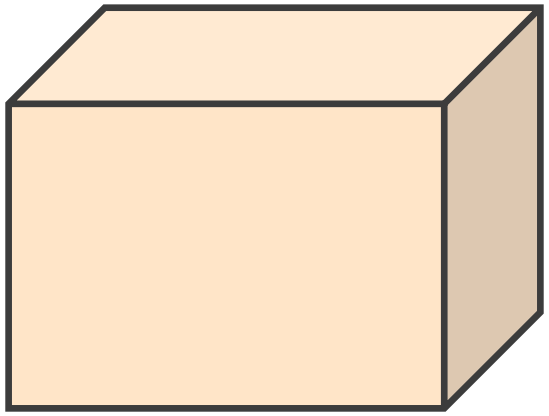
Homogenous and exponentially distributed trace sources

Trace sources can either be

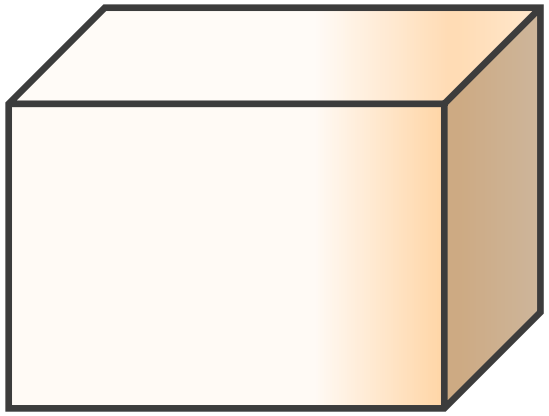
a) uniform: determined as activity per cm^3, total activity, or activity per gram

b) Exponentially distributed sources, starting from surface facing the detector

Trace sources are volumetric source-terms in the shielding's – they do not affect the attenuation of the shielding



Uniform trace source distribution



Exponential

$$f(z) = \frac{S_0}{L} e^{-z/L}$$

$S_0 = total\ activity\ (\frac{Bq}{m^2})$

$L = relaxation\ length\ (cm)$

63% of activity is within one relaxation length of the surface

Basic idea for analyzing soil measurements in InterSpec

In the “Activity/Shielding Fit” tool, use a shielding composed of soil that is effectively “infinitely large” with one or more trace sources

- The dimension along detector axis should be many attenuation lengths of highest energy peak used for analysis

  For 2614 keV, 2 meters in soil would attenuate 99.999% of gammas

- The radial (cylindrical) or width/height (rectangular) dimensions should be large enough to cover the detector’s field of view

  For detector 1-meter from ground, needed radius ranges from 15 m (homogeneous), to 210 m (pure surface)

- Increasing dimensions beyond the effectively infinitely large dimensions wont change answers

  i.e., for soil contamination, using cylinder with height 2 m, and radius 225 m is a good default to use

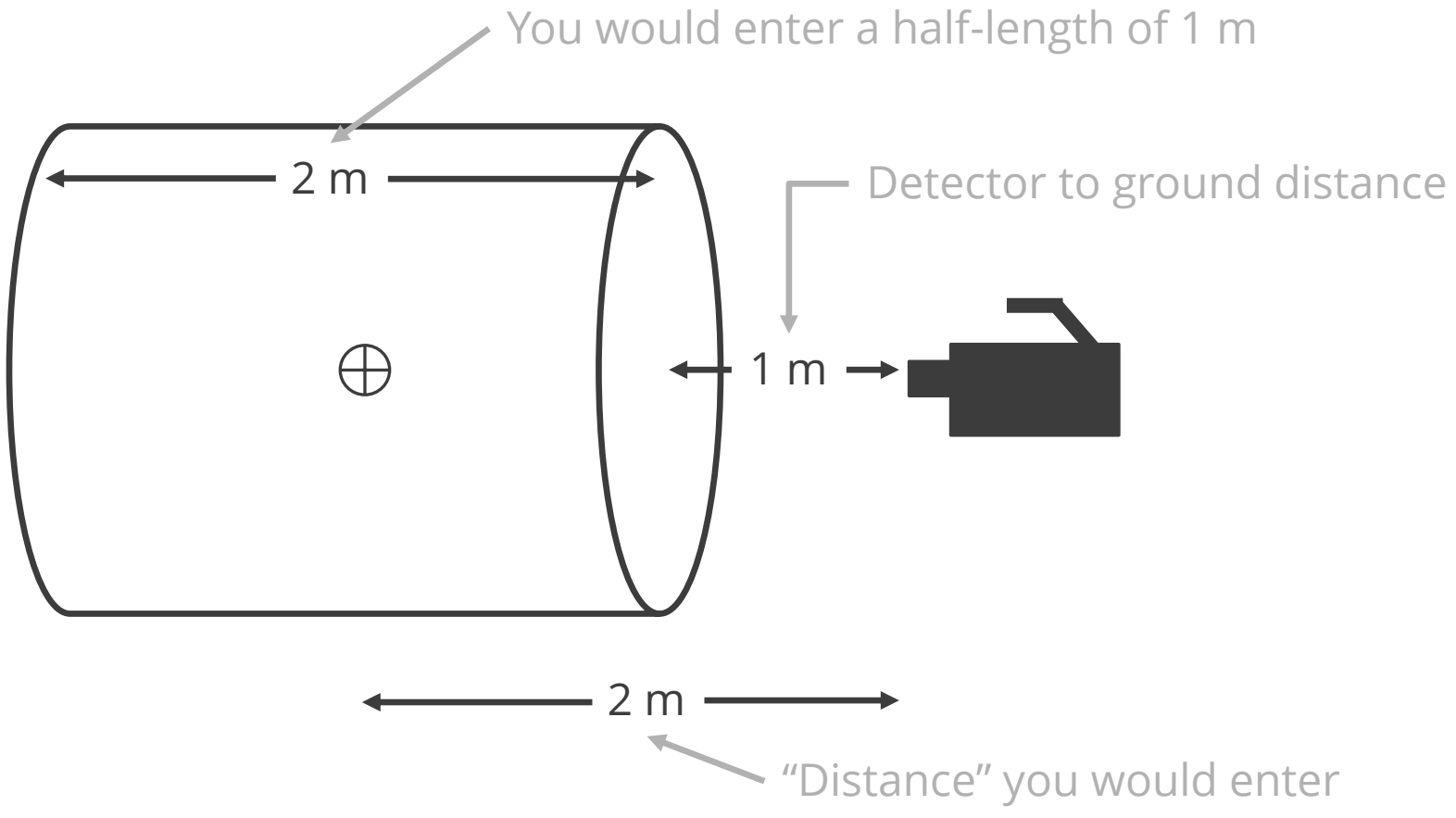
  Also, when an exponential distribution is selected, dimensions to use will be suggested

You will then fit for trace-source activitie(s)

Shielding geometries and distances in InterSpec

The “Distance” entered in the “Activity/Shielding Fit” tool is from the center of the shielding to the detector

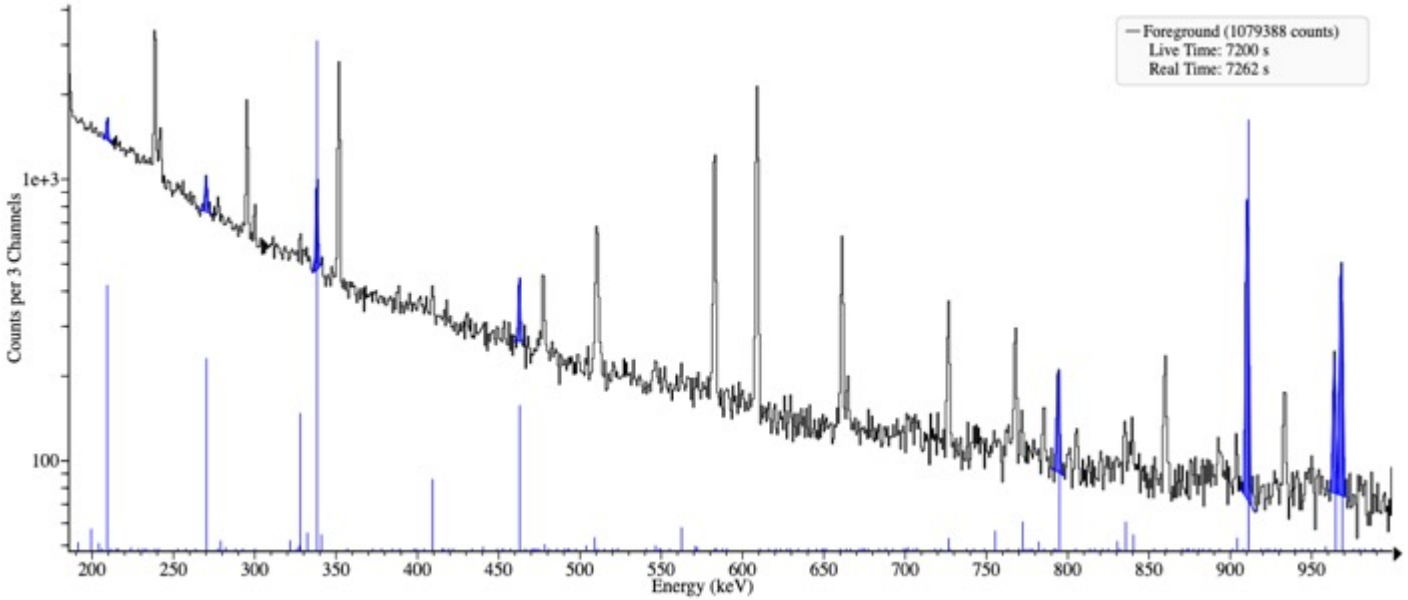
Example: if you want to represent soil as 2 meter thick, end-on cylinder, with detector 1 meter from the ground:



Case-study: NORM (Ac-228) concentration in soil

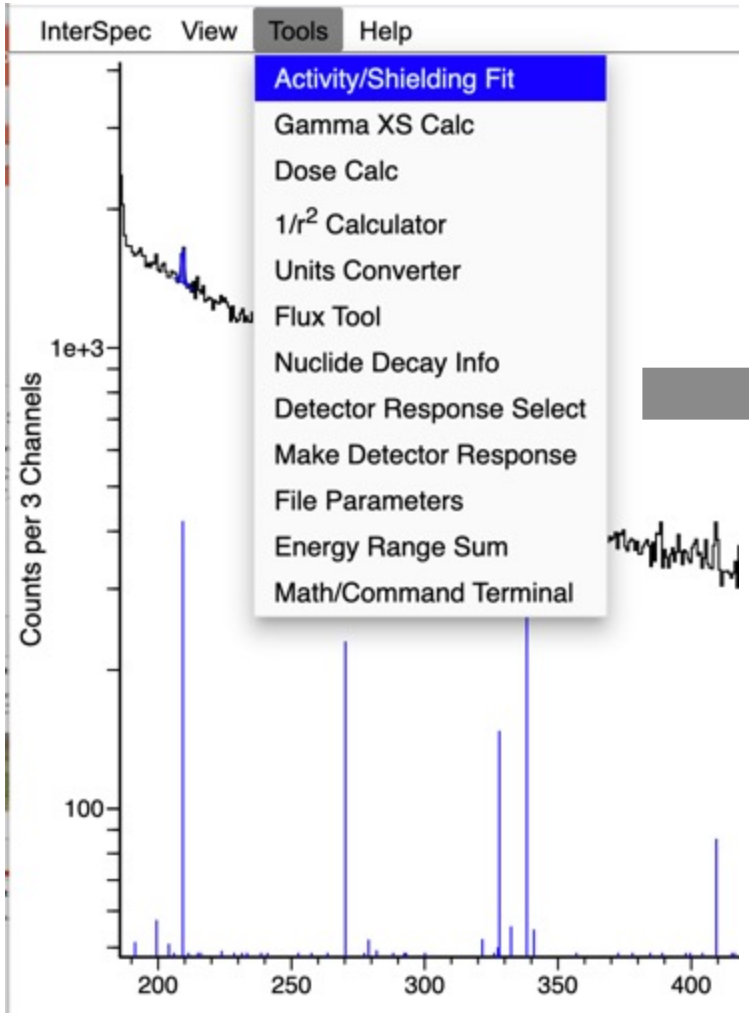
Step 1: Fit the dominant Ac-228 peaks in the spectrum

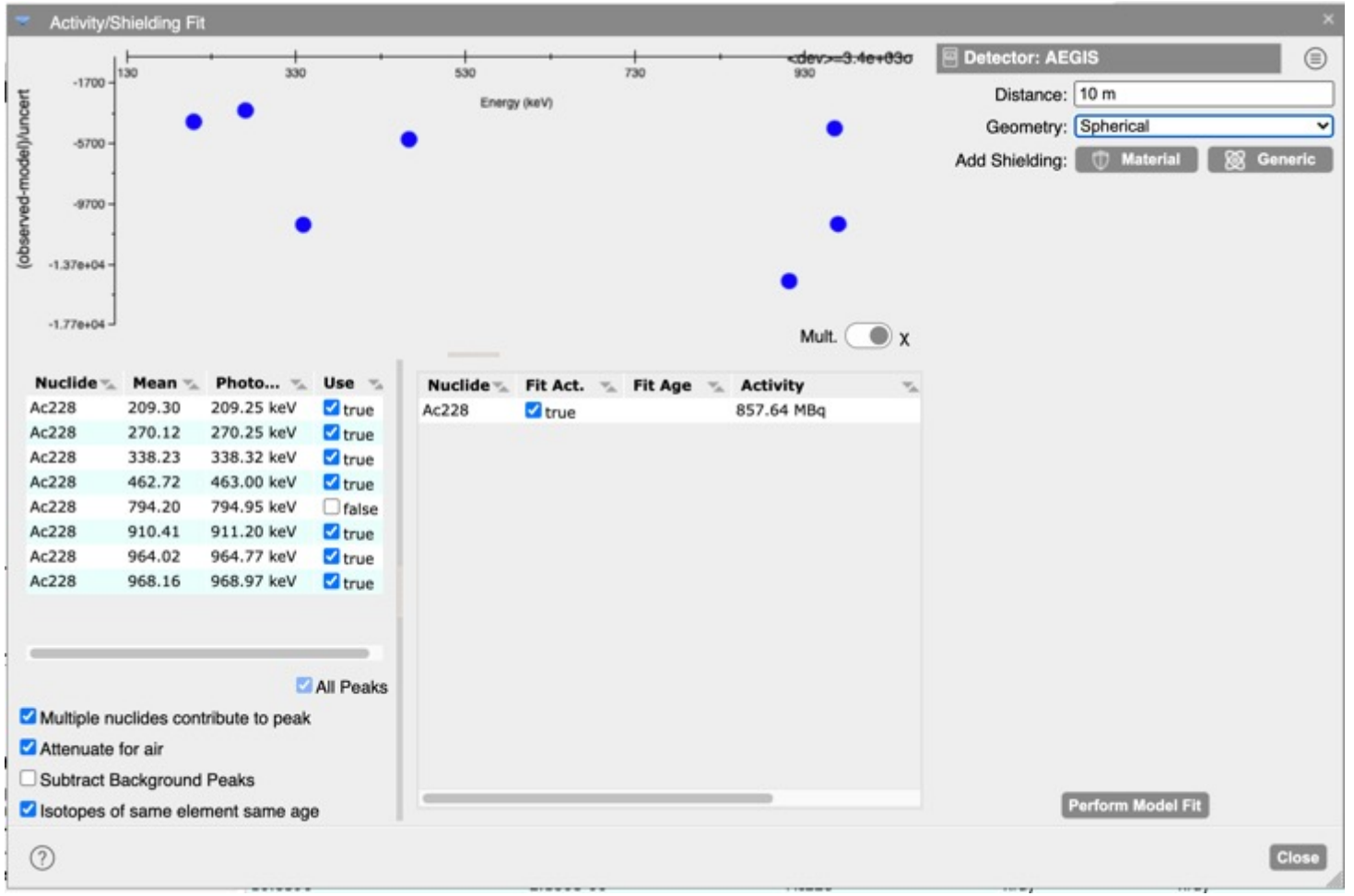
- Make sure you associate the peaks with Ac-228 by either showing Ac-228 reference lines before fitting the peaks, or manually typing in the association



Case-study: NORM (Ac-228) concentration in soil (cont)

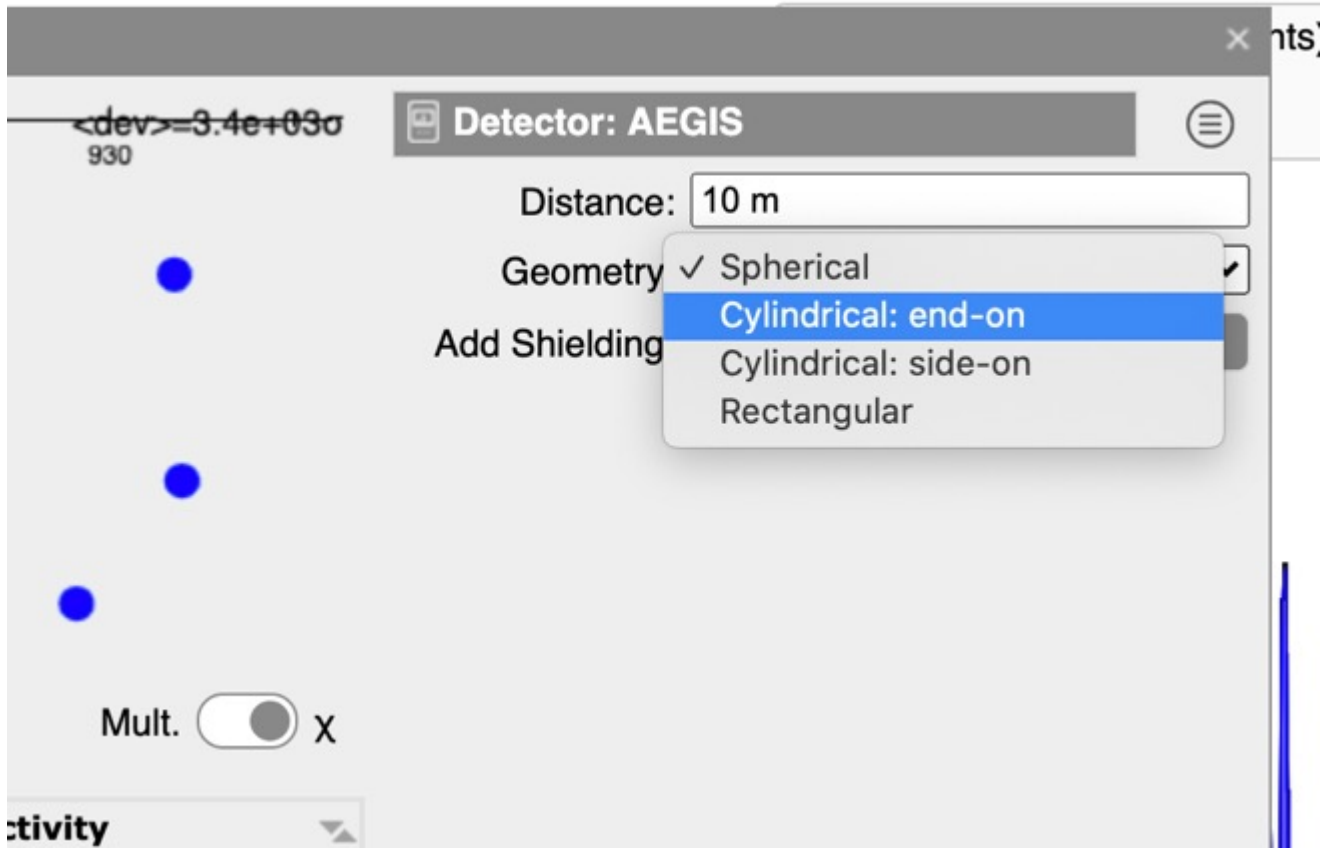
Step 2: go to the “Activity/Shielding Fit” tool





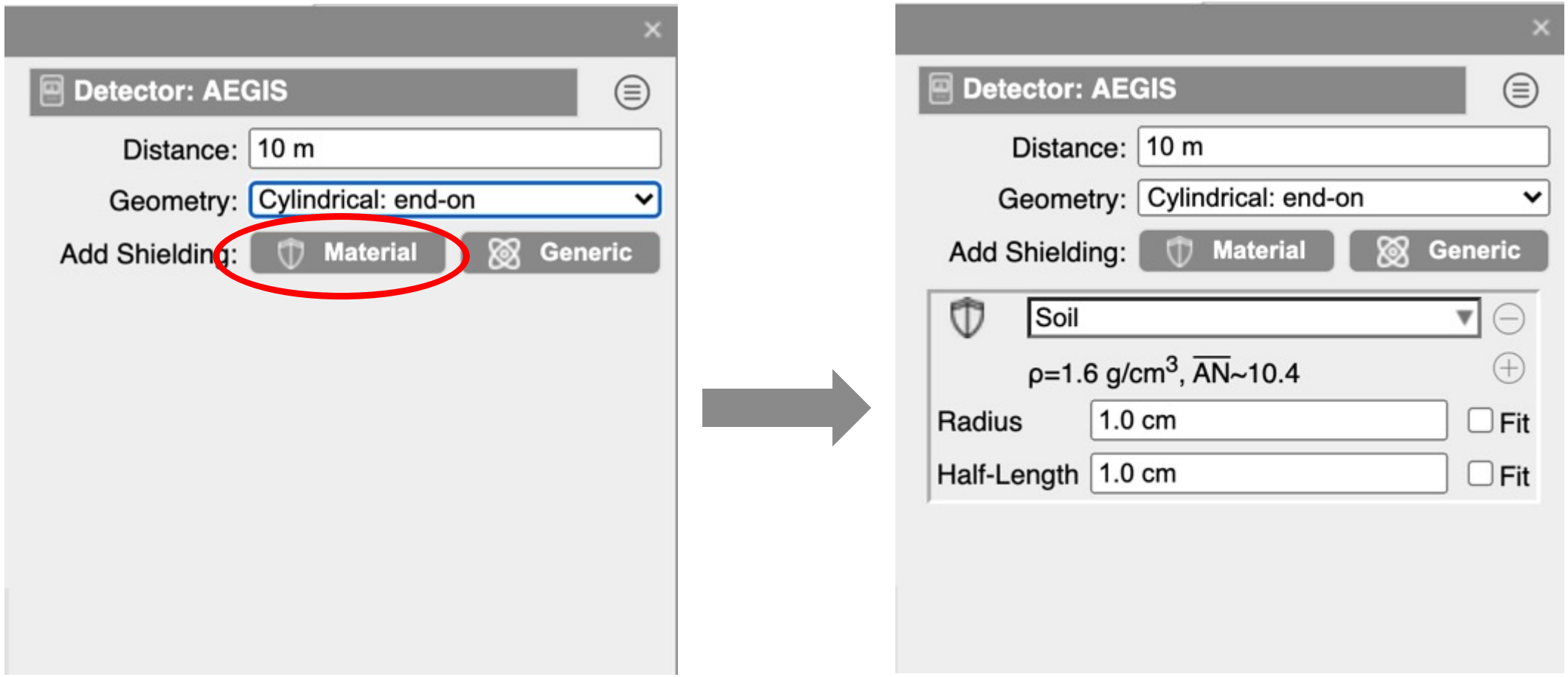
Case-study: NORM (Ac-228) concentration in soil (cont)

Step 3: select “Cylindrical: end-on” geometry, or “Rectangular”



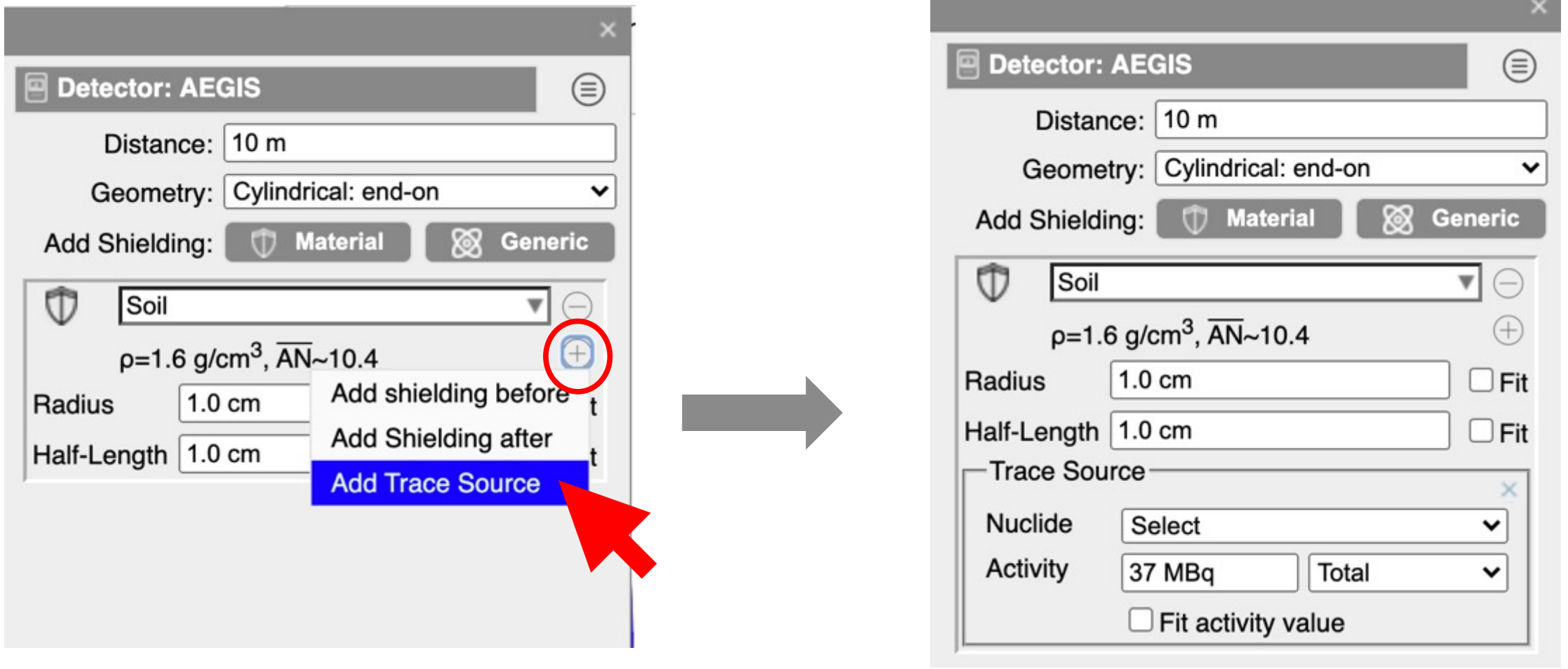
Case-study: NORM (Ac-228) concentration in soil (cont)

Step 4: Add a “Material” shielding, and choose “Soil” or other material



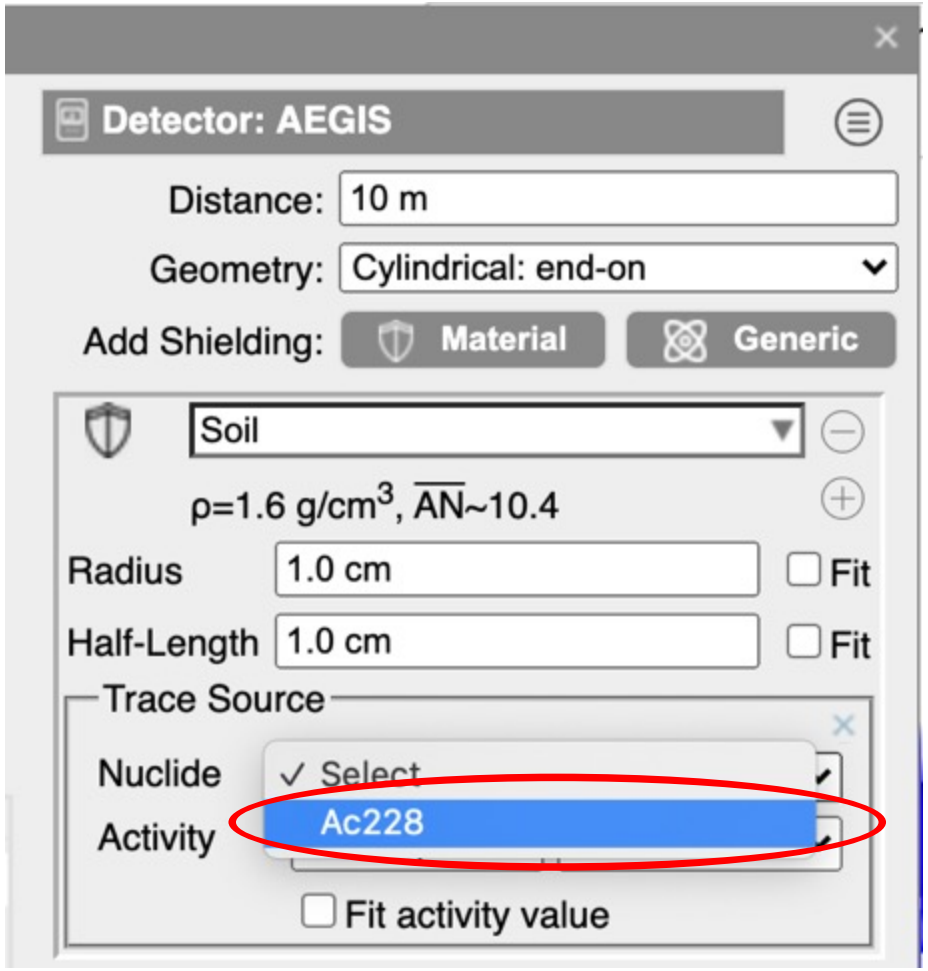
Case-study: NORM (Ac-228) concentration in soil (cont)

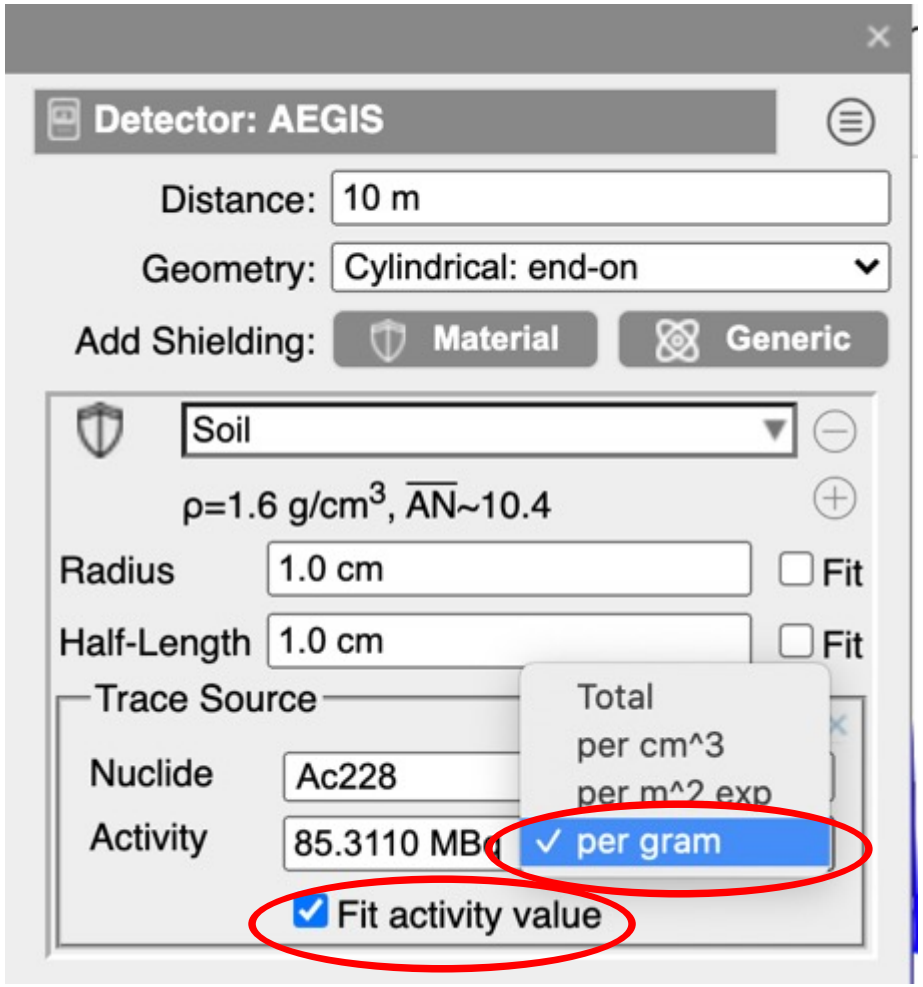
Step 5: Add a trace source by clicking on the “+” button



Case-study: NORM (Ac-228) concentration in soil (cont)

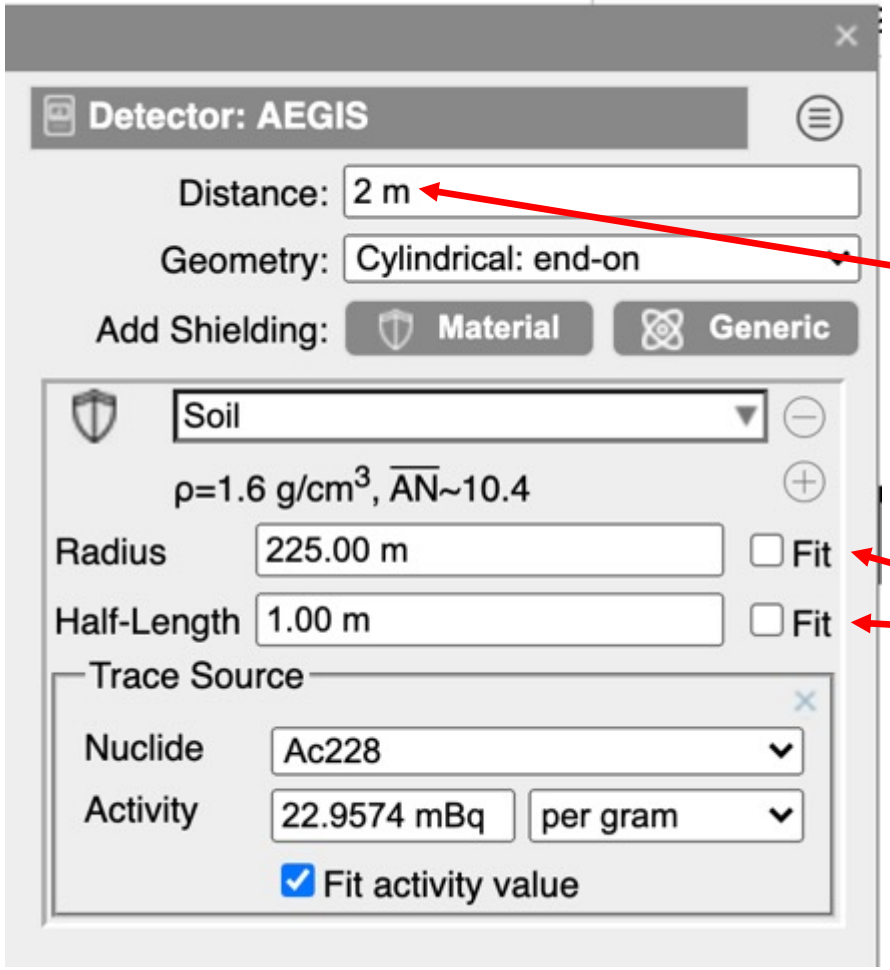
Step 6: Select “Ac228” as the trace source, select to fit activity, and choose activity type





Case-study: NORM (Ac-228) concentration in soil (cont)

Step 8: Enter in dimensions you want.
Ex., 50 m radius, and 2 m half-length (4 m total depth)



Detector was 1 meter from ground, but since using 1 meter cylinder half-length, distance is 2 meter to center of soil shielding

Make sure you aren't fitting for dimensions – this doesn't make sense in this context

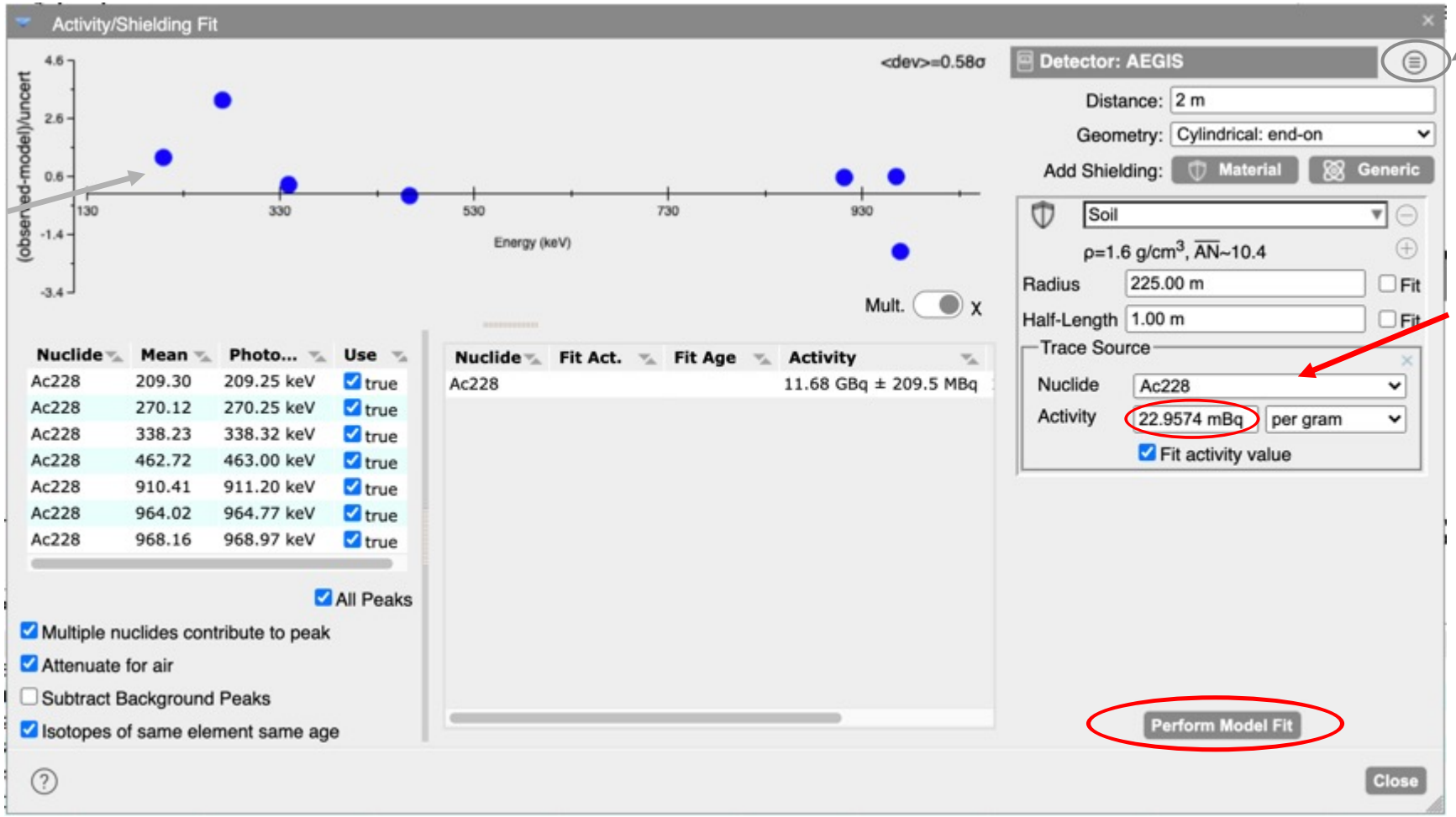
Case-study: NORM (Ac-228) concentration in soil (cont)

Step 9: Make sure you are are using correct detector response function, and other options selected as you want, and hit “Perform Model Fit”

Make sure your peaks are all within reasonable numbers of sigma of each other

Further calculation details available in log

Activity will be updated 23 mBq/gram

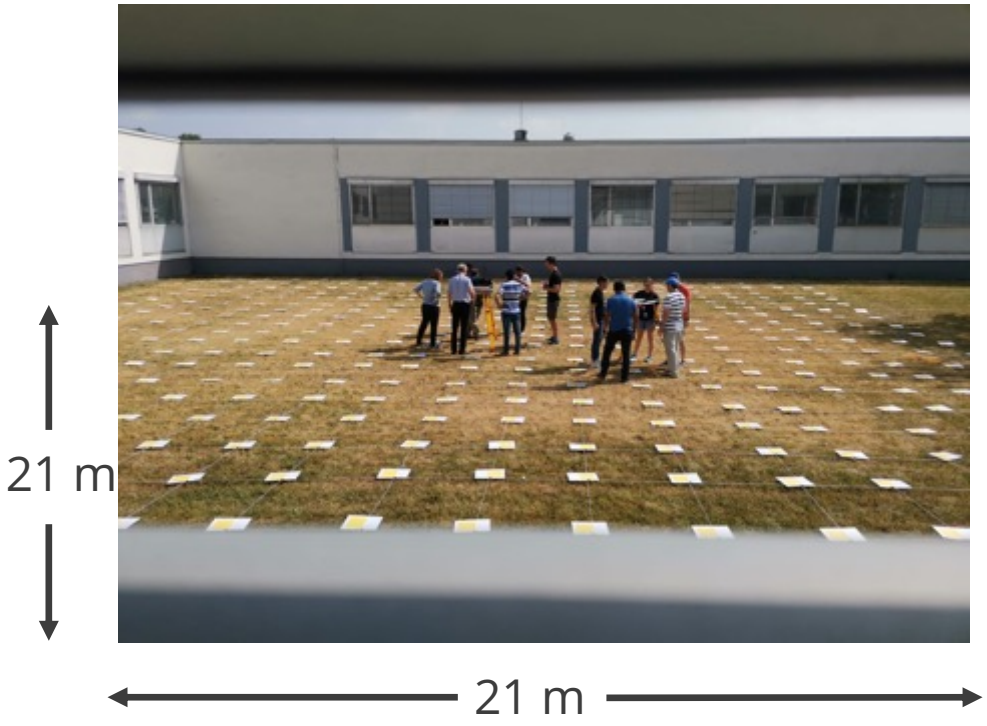


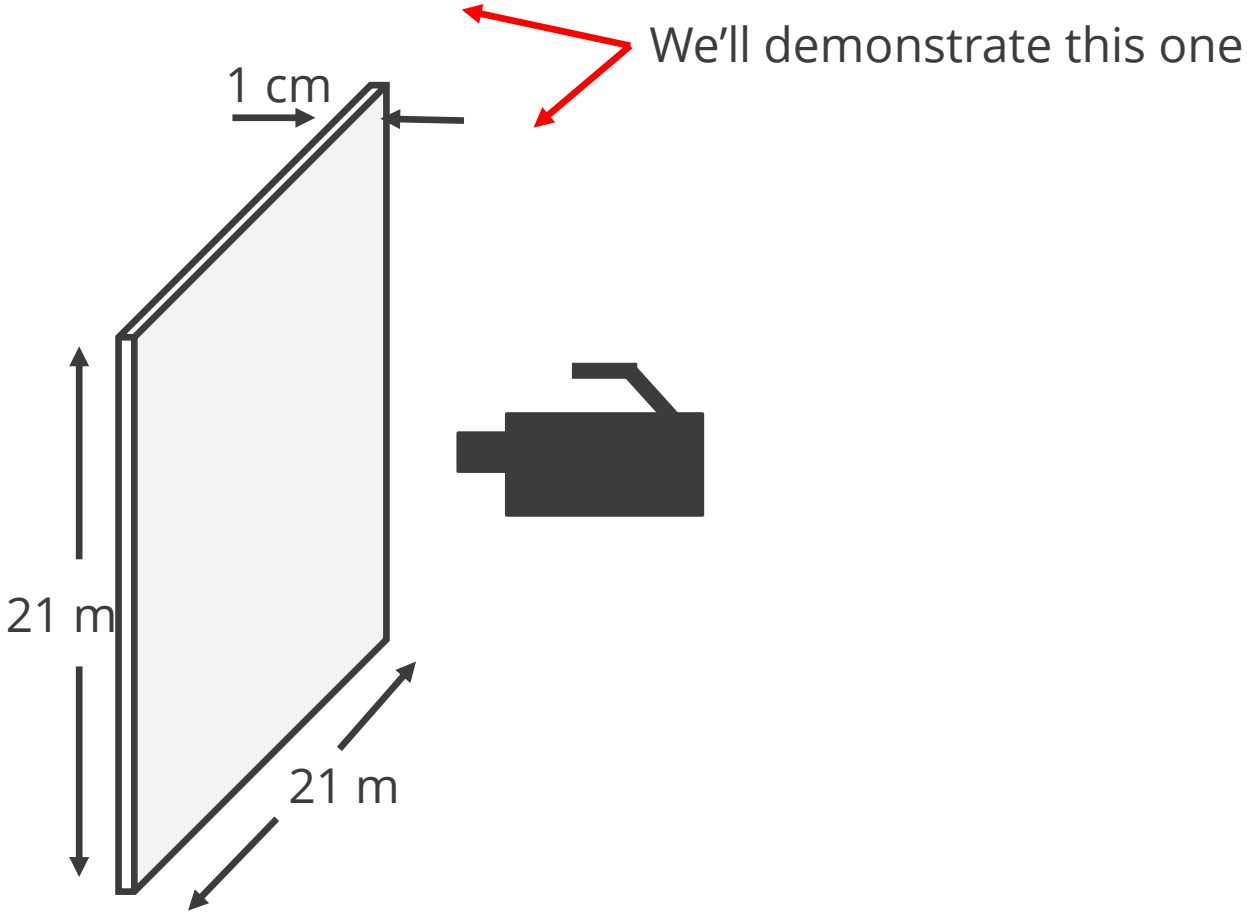
Case-study: Eu152 surface contamination (cont)

There are a couple ways you could represent this scenario

1. As an exponential surface contamination, with very short relaxation length
2. As a thin “air” volume, with uniform trace-source distribution

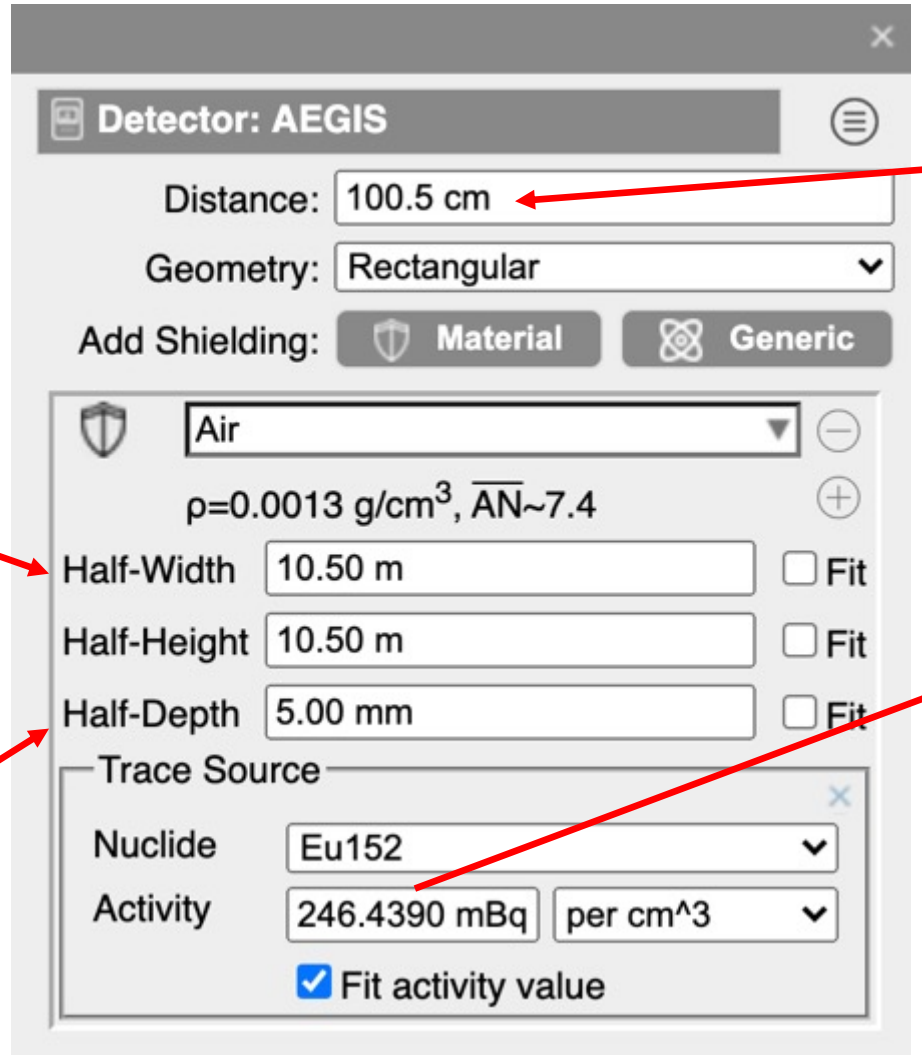
We’ll demonstrate this one





Case-study: Eu152 surface contamination (cont)

The steps for analysis is same as last example, but this time choose a rectangular geometry



Add 0.5 cm to distance to make up for 1 cm thickness

"Width" and "Height" are entered as half-values – this makes things easier when there are multiple layers

Choose a total thickness of 1 cm, for convenience

Multiplying by 1 cm, gives surface contamination of 246 mBq/cm^2
(known value: 252 mBq/cm^2)

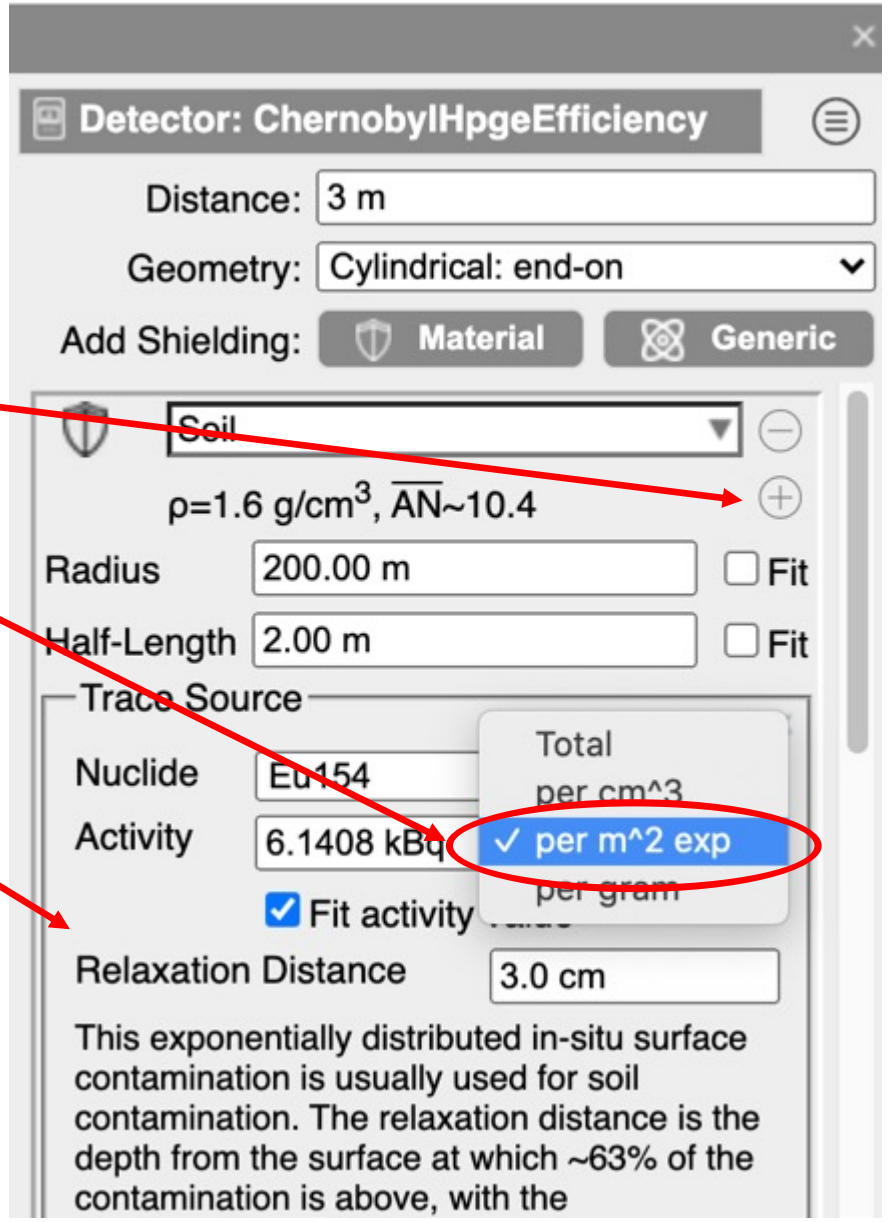
Case study: Chernobyl measurements

Do same steps as previous examples, but:

- fit peaks for Eu154, Cs137, Co60, and Cs134
- Use a end-on cylindrical, or rectangular geometry, with sufficiently large dimensions
- Add a trace source for each of the four nuclides
- Select "**per m^2 exp**" activity type – this will cause a "Relaxation Distance" enter form to appear
- Enter "3 cm" for relaxation distance

Chernobyl - Point 1

Nuclide	Activity
Eu154	6.24 ± 0.15 kBq/m²
Cs137	1.43 ± 0.01 MBq/m²
Co60	206.9 ± 14.2 Bq/m²
Cs134	368.78 ± 38.7 kBq/m²



Some warnings about these calculations in InterSpec

- Non-spherical geometries and trace sources are new capabilities added to InterSpec v1.0.9_rc1 – released today.
  - There are bound to be some improvements and issues that need to be fixed
- The angular response of the detectors is not taken into account.
  - Not typically a large effect (think 10%), but has not been rigorously evaluated
  - This is expected to be added in the future

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Comparison of results

Eu152 - 21m x 21m surface contamination

	Truth	InterSpec	ISOCS	ISOTOPIC PS	ISOTOPIC %
AEGIS	**2520 bq/m²**	2459 ± 18 bq/m²	2632 ± 62 bq/m²	2601 ± 86 bq/m²	2309 ± 44 bq/m²
MicroDetective	**2520 bq/m²**	2349 ± 41 bq/m²	—	2834 ± 93 bq/m²	2406 ± 73 bq/m²

Ac228 Homogeneous

	LabSOCS	InterSpec	ISOCS	ISOTOPIC PS	ISOTOPIC %	Manual
AEGIS	—	23.7 ± 0.4 bq/kg	26.15 ± 0.89 bq/kg	23.92 ± 2.25 bq/kg	20.87 ± 0.94 bq/kg	21.14 ± 1.68 bq/kg
MicroDetective	—	20.8 ± 0.8 bq/kg	—	25.70 ± 2.26 bq/kg	25.59 ± 2.23 bq/kg	—
Lab	**21.30 ± 0.40 bq/kg**	—	—	—	—	—

Chernobyl - Point 1

Nuclide	InterSpec	ISOTOPIC
Eu154	6.24 ± 0.15 kBq/m²	6.61 ± 0.16 kBq/m²
Cs137	1.43 ± 0.01 MBq/m²	1.47 ± 0.01 MBq/m²
Co60	206.9 ± 14.2 Bq/m²	245.6 ± 22.6 Bq/m²
Cs134	368.78 ± 38.7 kBq/m²	349.5 ± 70.6 Bq/m²