# Lesson 4

**Your first GEANT4 simulation!**

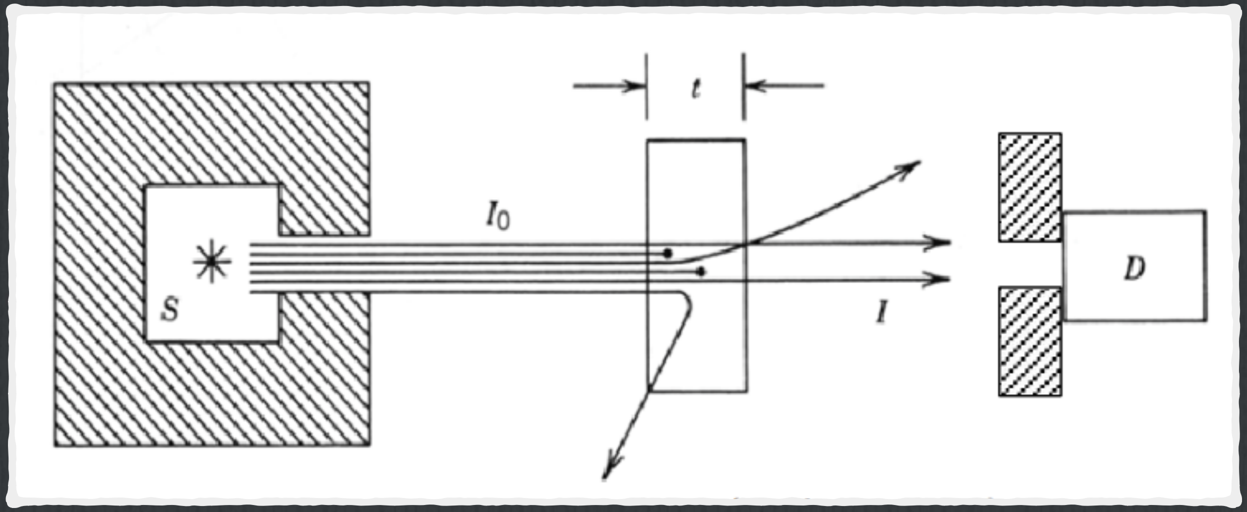
# Shielding against gamma-rays

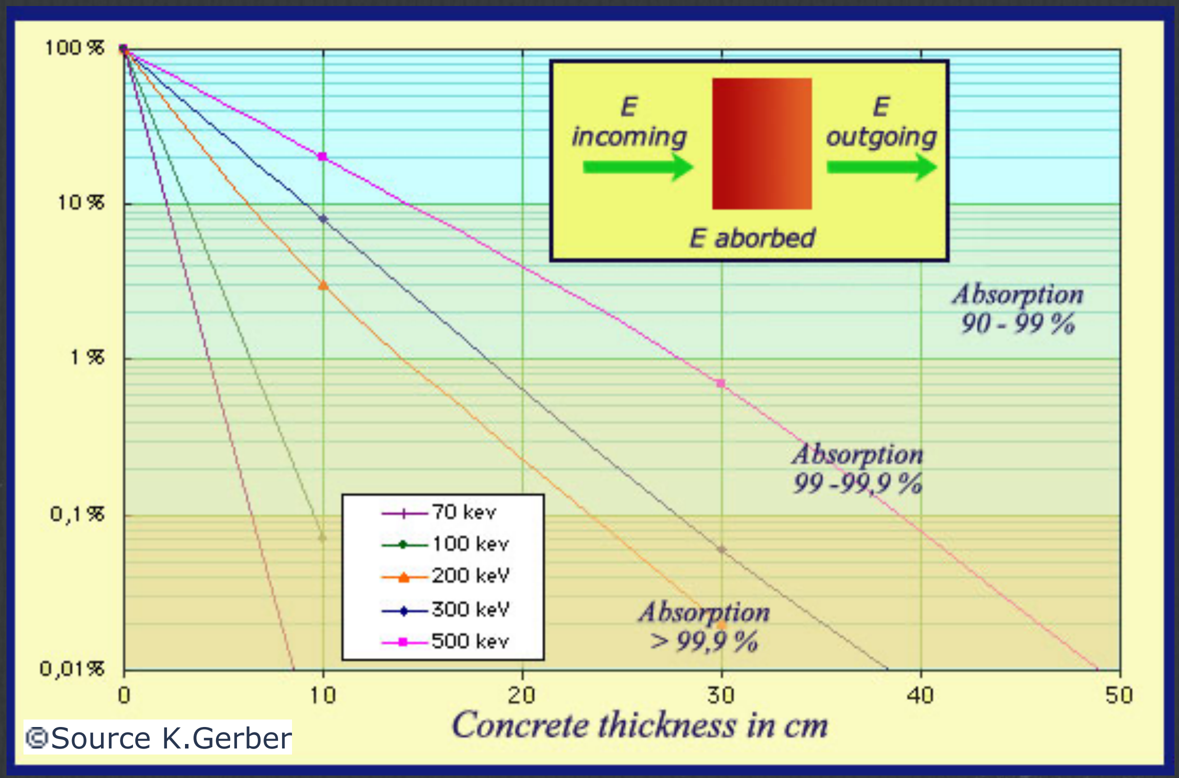
- What is the required thickness of Pb to reduce the intensity of a beam of gamma rays to $1/10^{th}$ of its initial value?
  - This is known as the "Tenth Value Layer", TVL
- Consider a collimated beam of photons with 1 MeV
- Get the energy distribution of the gammas that get to the other side
  - What is the energy of the photons that get through?
  - Why do we seem to see two populations in the energy spectrum?
  - Do the simulation results agree with what you expected?
- Bonus: also get the position distribution of the exit gammas

# Shielding against gamma-rays

- Start with the Shielding.zip simulation structure
  - You already have all the classes required, but mostly empty
  - Define your materials and create the geometry elements
    - what volumes do you need?
    - start by estimating the required shield thickness analytically
      - note that this seems trivial for a mono-energetic source,
        but that's not the case for a realistic source with a wide energy spectrum
  - Define your primary particles
  - Output relevant information
    - start with just the gamma energy in the detector
    - then add information about the position
  - There is a very simple ROOT script in the folder (*analysis.C*), use it to create the relevant plots

# Photon beam attenuation coefficient




- The attenuation depends on:
  - photon energy
  - medium (material & density)
- For a homogeneous medium

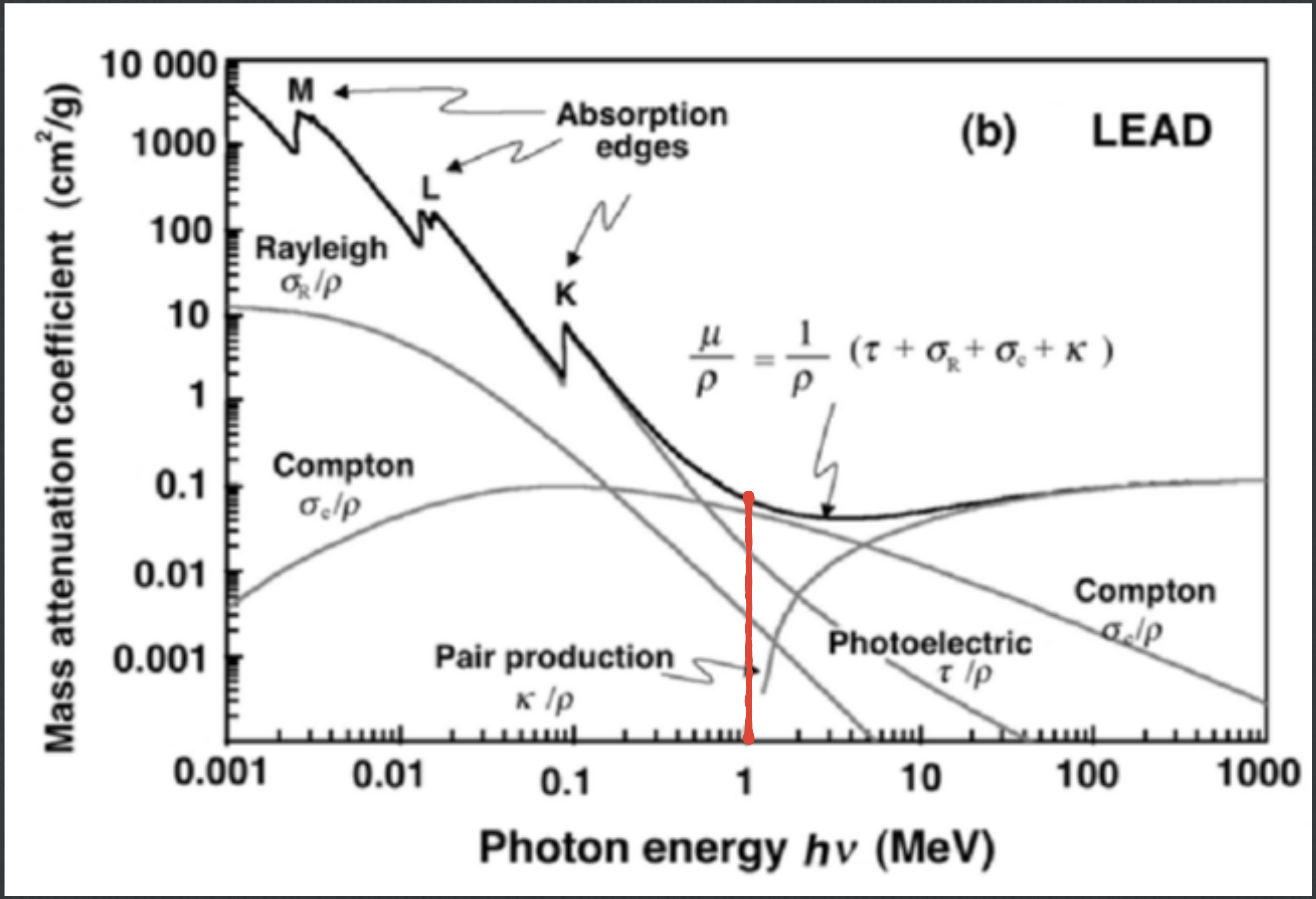
$$I(x) = I_0 \exp(-\mu x)$$

- where

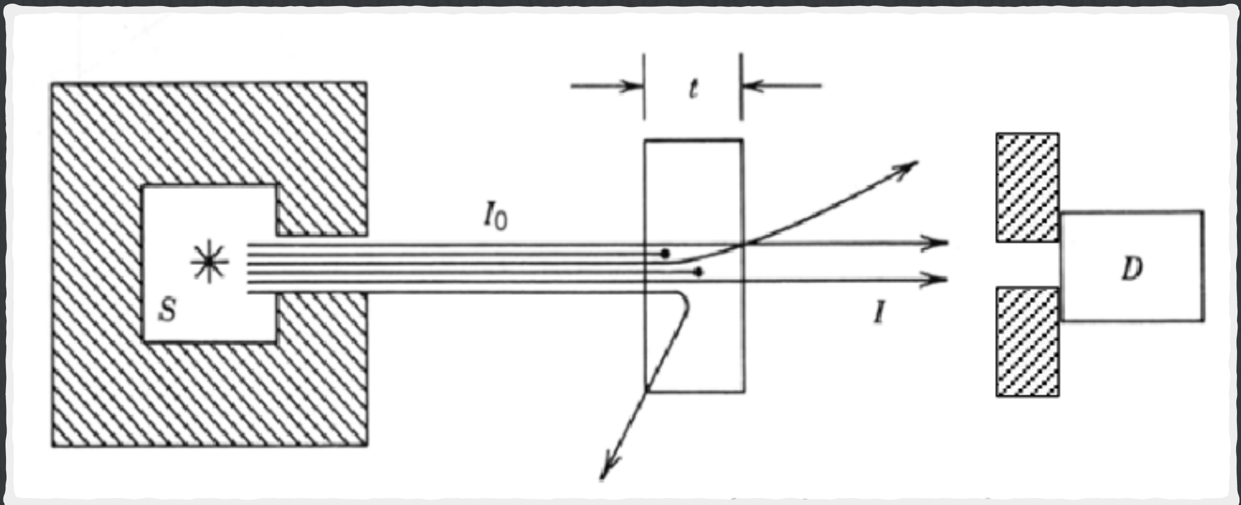
$$\mu = \mu_{pe} + \mu_c + \mu_p$$

Includes contributions from all possible processes

# Attenuation coefficient in Pb



# Photon beam attenuation coefficient




- The attenuation depends on:
  - photon energy
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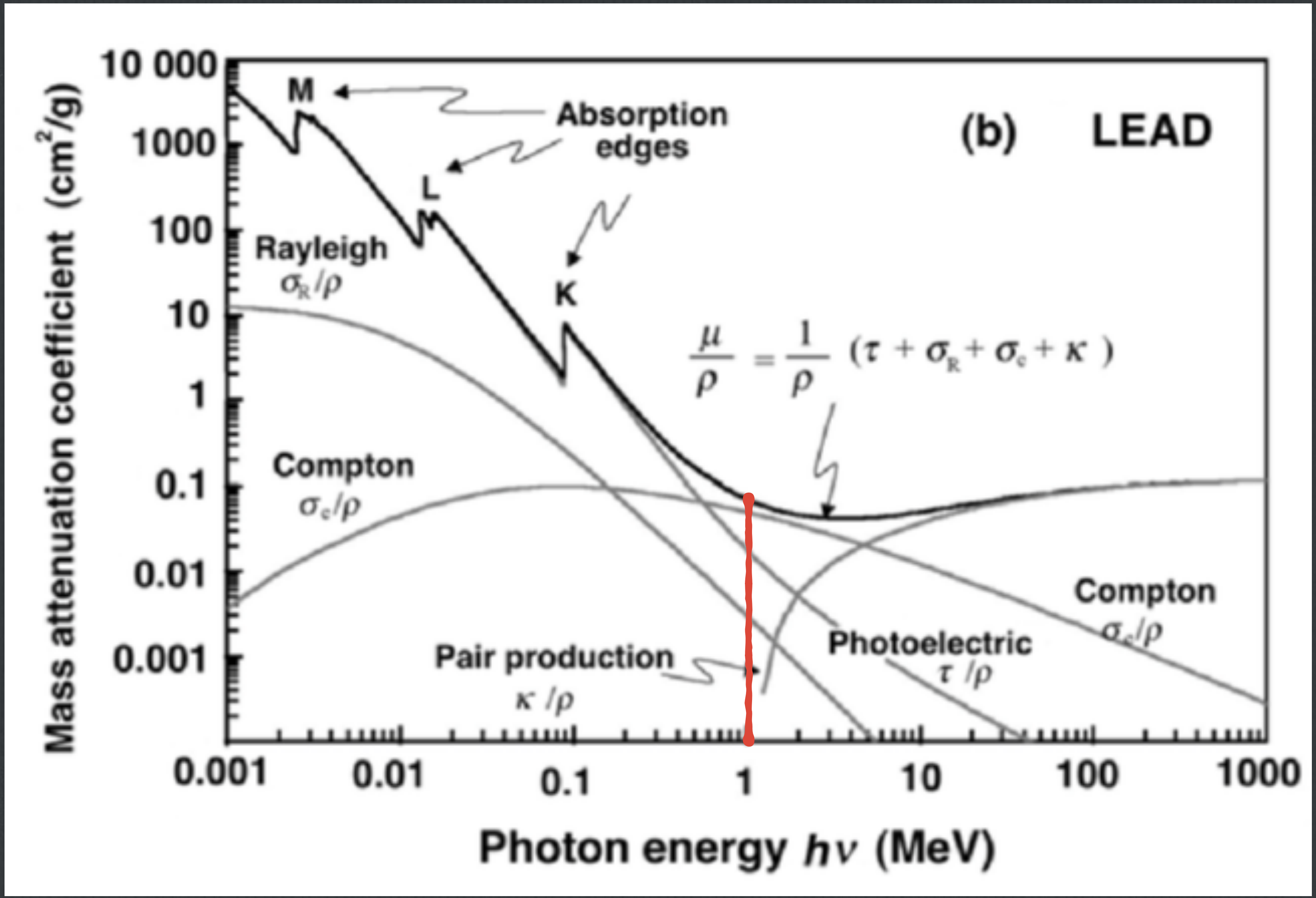
**Table 7.8.** Characteristic absorber thicknesses and their effects upon beam intensity attenuation

| *Absorber thickness* | $\frac{I(x)}{I(0)}$ | $100\frac{I(x)}{I(0)}$ | *Name* | *Symbol* |
|---|---|---|---|---|
| $(\ln 2)/\mu$ | 0.500 | 50.0% | *Half-Value Layer* | $HVL = x_{1/2}$ |
| $1/\mu$ | 0.368 | 36.8% | *Mean Free Path* | $MFP = \bar{x}$ |
| $(\ln 10)/\mu$ | 0.100 | 10.0% | *Tenth-Value Layer* | $TVL = x_{1/10}$ |

# Attenuation coefficient in Pb

https://physics.nist.gov/PhysRefData/XrayMassCoef/tab3.html




1 MeV -> $\mu_m = 7.102 \times 10^{-2}$ cm²/g

# Setting up the simulation

- The fundamental blocks

1. Define materials needed (which ones?)
2. Create a Lead target volume, with the required thickness
   (you can copy the required code from last week's example)
   A. Optionally, give your volumes different colours
3. Define your primary particles
   (again, feel free to copy from last week's example)
4. Define the physics — we'll use one of G4's lists, recommended for shielding applications
5. You should now be able to compile (make) and run (Shielding) the simulation

# Setting up the simulation

- Collecting information

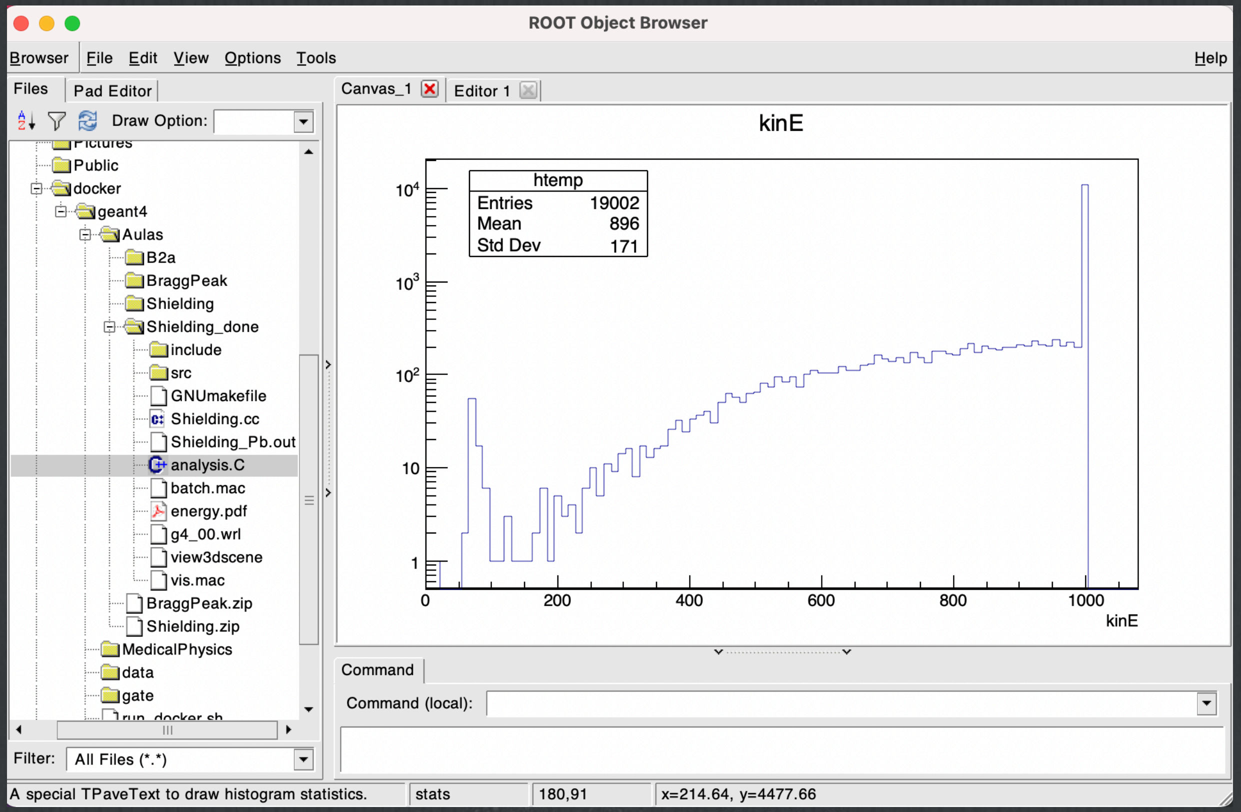
1. Create a detector volume, some distance from the target
   (make this small, to ensure we mostly detect direct gammas)
2. Check your geometry with the new volume, make sure it looks as you expected
   (no overlaps, correct positioning)
3. Record gammas that get to the detector to a text file
   (again, you can copy from last week's example)
   A. Kill the gamma after you register it (to avoid duplication)
4. Use the interactive mode to run some events and make sure the text file is being written with the information you expected
5. Run the simulation in batch mode with a large number of events (1M)
   A. Use the batch.mac macro file

# Analysing the results

1. Open root, and execute the analysis.C script
   - root -l
   - .x analysis.C
2. Use log scale for the Y axis (View->Editor, click Log Scale Y)
3. Quick conclusions:
   A. Looks like we have slightly more than 10% of the initial gammas — why?
   B. Looks like we have 2 populations — which ones, and what do they correspond to?
4. Isolate the populations using an energy cut

# Quick ROOT tip

- Did you know that ROOT has a graphical interface?
- Open ROOT, and type:
  - new TBrowser
- You can edit and execute your analysis scripts directly in the interface!



# Bonus

- Get the positions of the exiting gammas

1. Make your detector “infinitely” large in the perpendicular plane
2. Move it very close to the target (no overlaps!)
3. Make it very thin (to minimise parallax)
4. Add recording of the position to your output files
5. Analyse the output — this is an approximation to the Compton scatter angular distribution
    A. Make sure you exclude direct gammas from the plot!
    B. Why is it an “approximation”?

# For the report…

- Describe what we wanted to simulate
- Discuss how you estimated the required Pb thickness
- Describe how you implemented the simulation (geometry, primaries, collecting info for analysis)
- Discuss the results from the analysis, add relevant plots