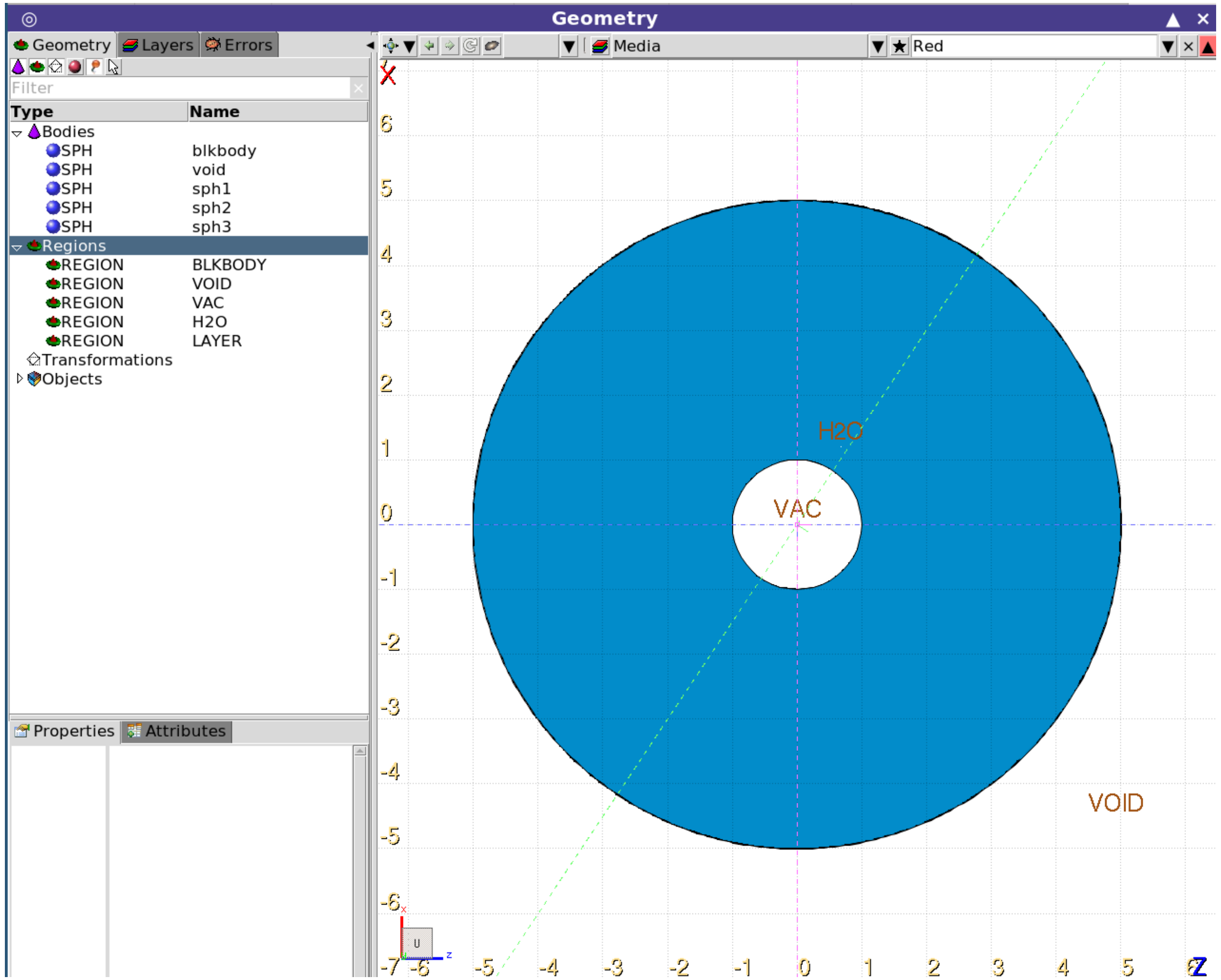
# Exercise: low-energy neutronics

# Exercise objectives

- Get familiar with FLUKA's pointwise treatment of low-energy neutrons and its advantages over a group-wise approach
- Witness how various neutron cross section features manifest in neutron fluences
- Master the plotting of histograms in logarithmic abscissas (lethargy units)
- Further practice with pre-processor directives
- Let's try to complete tasks 1-4, task 5 left as optional (examining crystal binding effects on the neutron fluence)

# 01 – Geometry (provided)




- Consists of three spheres:
  - `sph1`, R = 1 cm
  - `sph2`, R = 5 cm
  - `sph3`, R = 5 cm + 100 μm

- …and corresponding regions:
  - `VAC`: the inside of `sph1`, material: `VACUUM`
  - `H2O`: outside of `sph1`, inside `sph2`, material: `WATER`
  - `LAYER`: outside of `sph2`, inside `sph3`, material: `VACUUM`

# 01 – Source, preprocessor, LOW-PWXS, scoring (provided)

- **Source** (isotropic 1 MeV neutron source):

| | | | |
|---|---|---|---|
| BEAM | Beam: Energy ▾ | E: =-1*MeV | Part: NEUTRON ▾ |
| Δp: Flat ▾ | Δp: | Δϕ: Isotropic ▾ | |
| Shape(X): Rectangular ▾ | Δx: | Shape(Y): Rectangular ▾ | Δy: |
| Define the beam position | | | |
| BEAMPOS | x: | y: | z: |
| | cosx: | cosy: | Type: POSITIVE ▾ |

- **Preprocessor** directives:

```
#define pw
#define 10B
#define Cd
#define graphite
#define binding
```

- `LOW-PWXS` conditional on `pw`:

| | | | |
|---|---|---|---|
| #if pw ▾ | | | |
| LOW-PWXS | Mat: ▾ | to Mat: ▾ | Step: |
| db: ▾ | IAZ: | S(α,β): ▾ | T: |

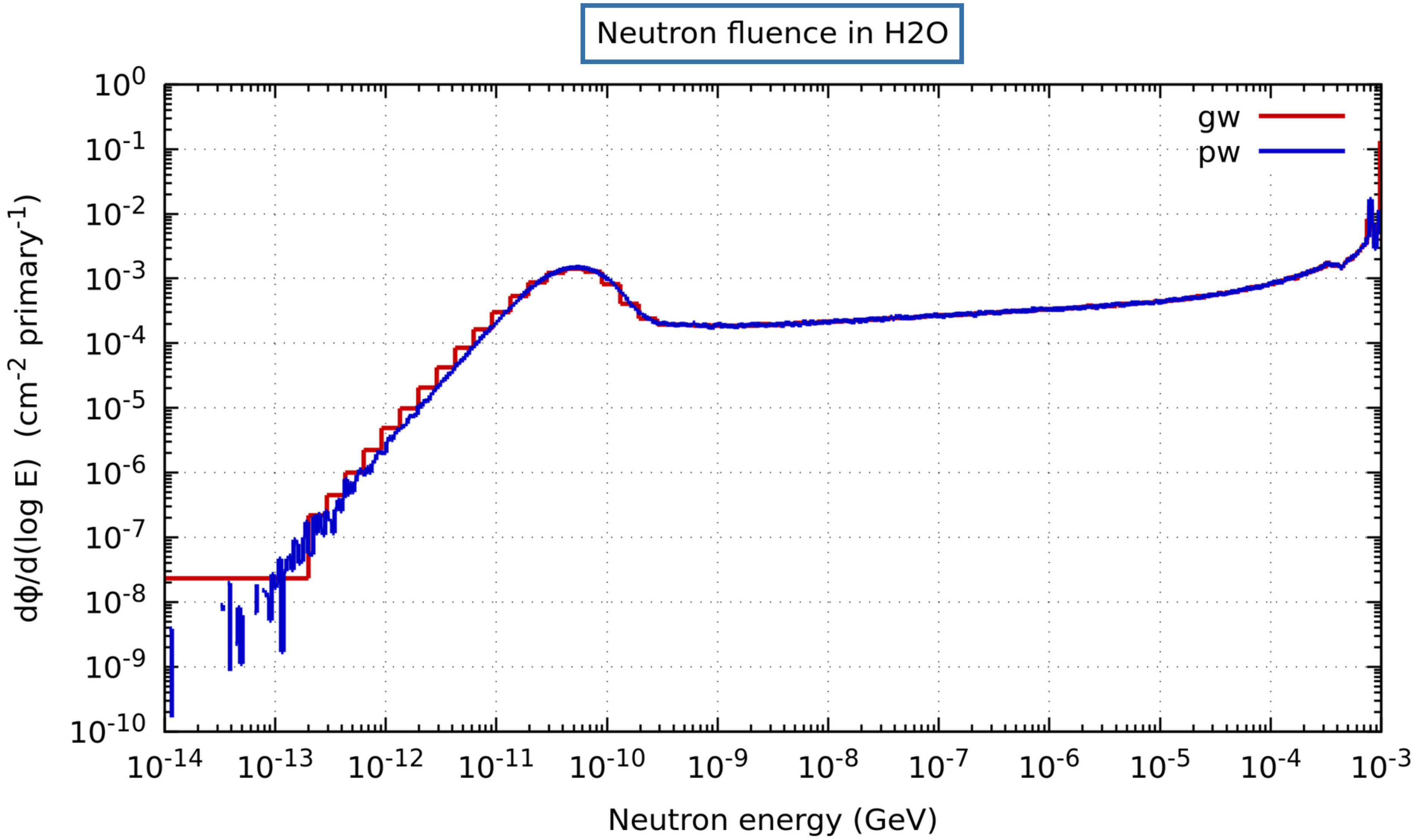
- **Scoring** (n fluence in the water and n fluence from the external layer to the void:

| | | | |
|---|---|---|---|
| USRTRACK | | Unit: 21 BIN ▾ | Name: n_water |
| Type: Log ▾ | Reg: H2O ▾ | | Vol: =4/3*pi*(body(sph2,4)**3-body(sph1,4)**3) |
| Part: NEUTRON ▾ | Emin: 1E-14 | Emax: =1*MeV | Bins: 500 |
| USRBDX | | Unit: 22 BIN ▾ | Name: n_emitted |
| Type: Φ1,LogE,LinΩ ▾ | Reg: LAYER ▾ | to Reg: VOID ▾ | Area: =4*pi*body(sph3,4)**2 |
| Part: NEUTRON ▾ | Emin: 1E-14 | Emax: =1*MeV | Ebins: 500 |
| | Ωmin: | Ωmax: | Ωbins: |

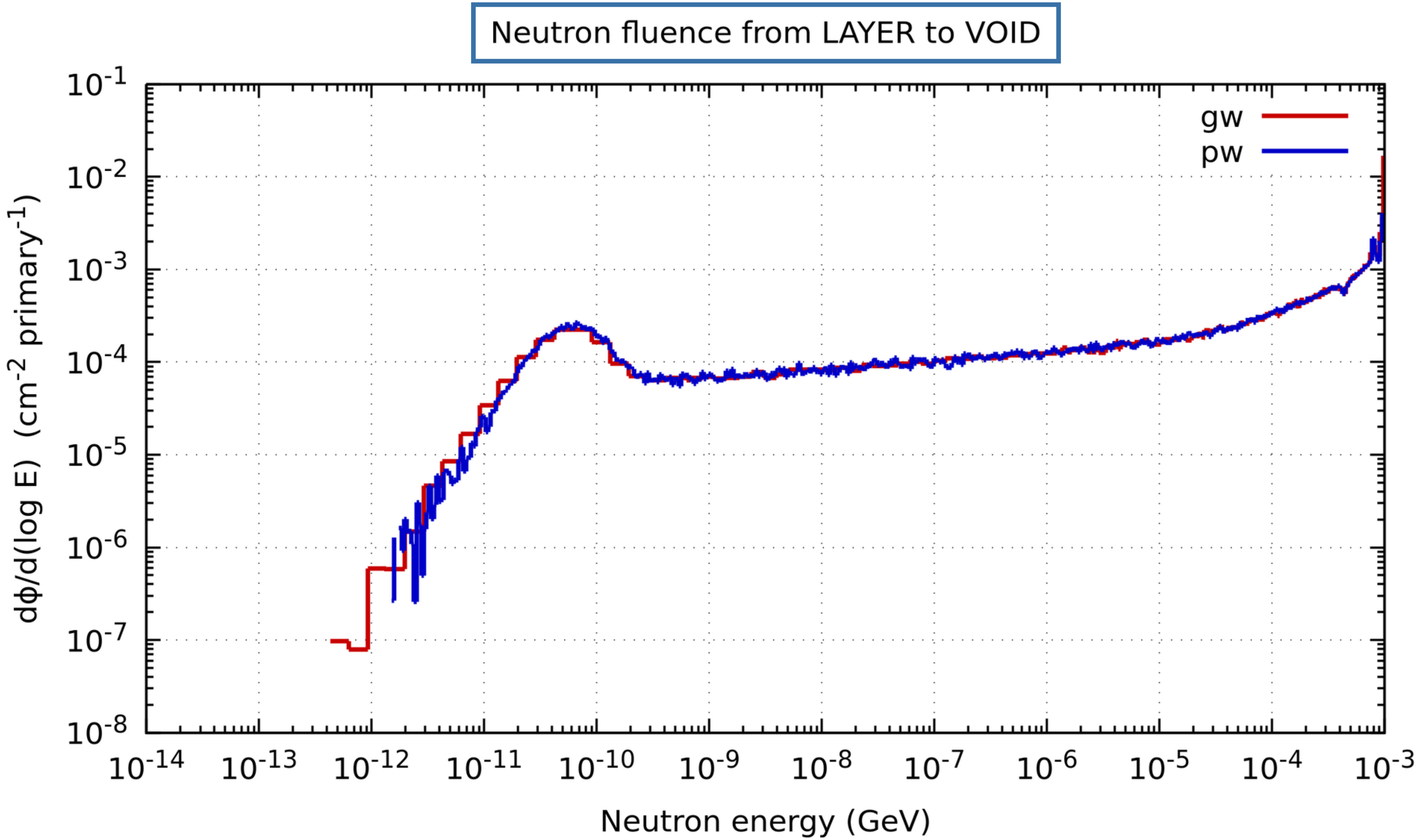
# 01 – Run, process, and plot

- Go to the Run tab and get ready to run the two already prepared runs:
  - `run/pw` with the `pw` directive active
  - `run/gw` with the `pw` directive inactive
- Both with 5 cycles, 25000 primaries per cycle
- Run! Process! Go to the Plot tab, and complete the placeholder plots:
  - "fluence_in_water": Plot the output from unit 21 of both runs in the same plot
  - "fluence_from_layer_to_void": Plot the output from unit 22 of both runs in the same plot
  - Log scale Y
  - **Log scale X: please take measures to avoid misrepresenting spectra (lethargy scale!)**
  - Add appropriate labels for the X and Y axes
- For gnuplot gourmands: `set xtics 10`; `set ytics 10`; `set grid;`
  `set form xy "10^{%L}"`
- Can you explain the differences in the two results?

# 01 – GW vs. PW – Results



# 01 – GW vs. PW – Results



# 02 – Thin layer of $^{10}B$

- All subsequent runs are with pointwise interactions (`pw` active)

- Conditionally to the `10B` preprocessor variable being active:
  - Material `BORON10` is assigned to the 100 μm `LAYER` region
  - Note the **`MATERIAL`** card defining the `BORON10` material (monoisotopic boron with $^{10}B$, not natural composition)

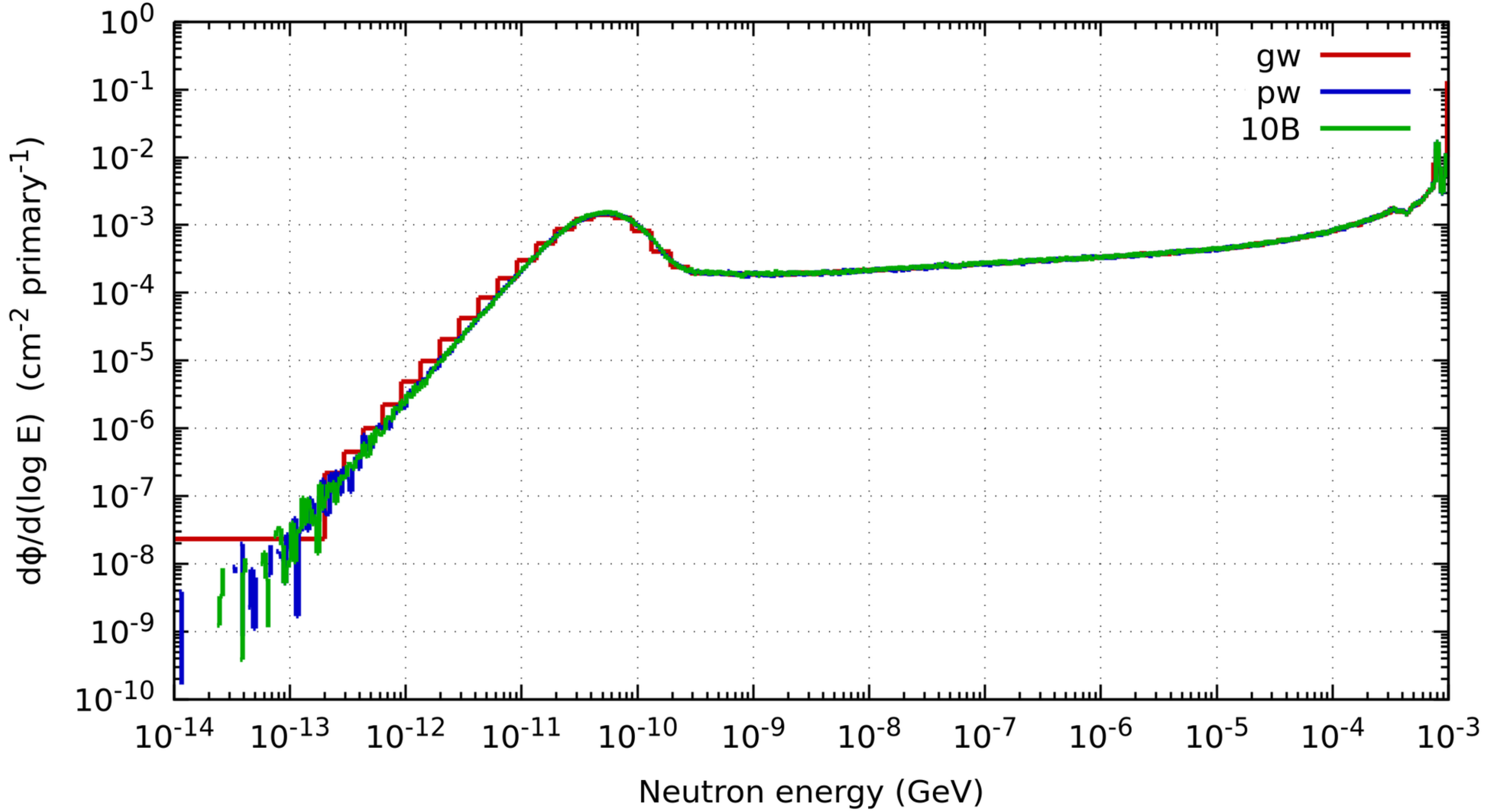
- Add a new `run/10B` with both `pw` and `10B` variables active (all other variables off)
  No more group-wise runs from now on.

- Run! Process!
- Add the n fluences to the two plots

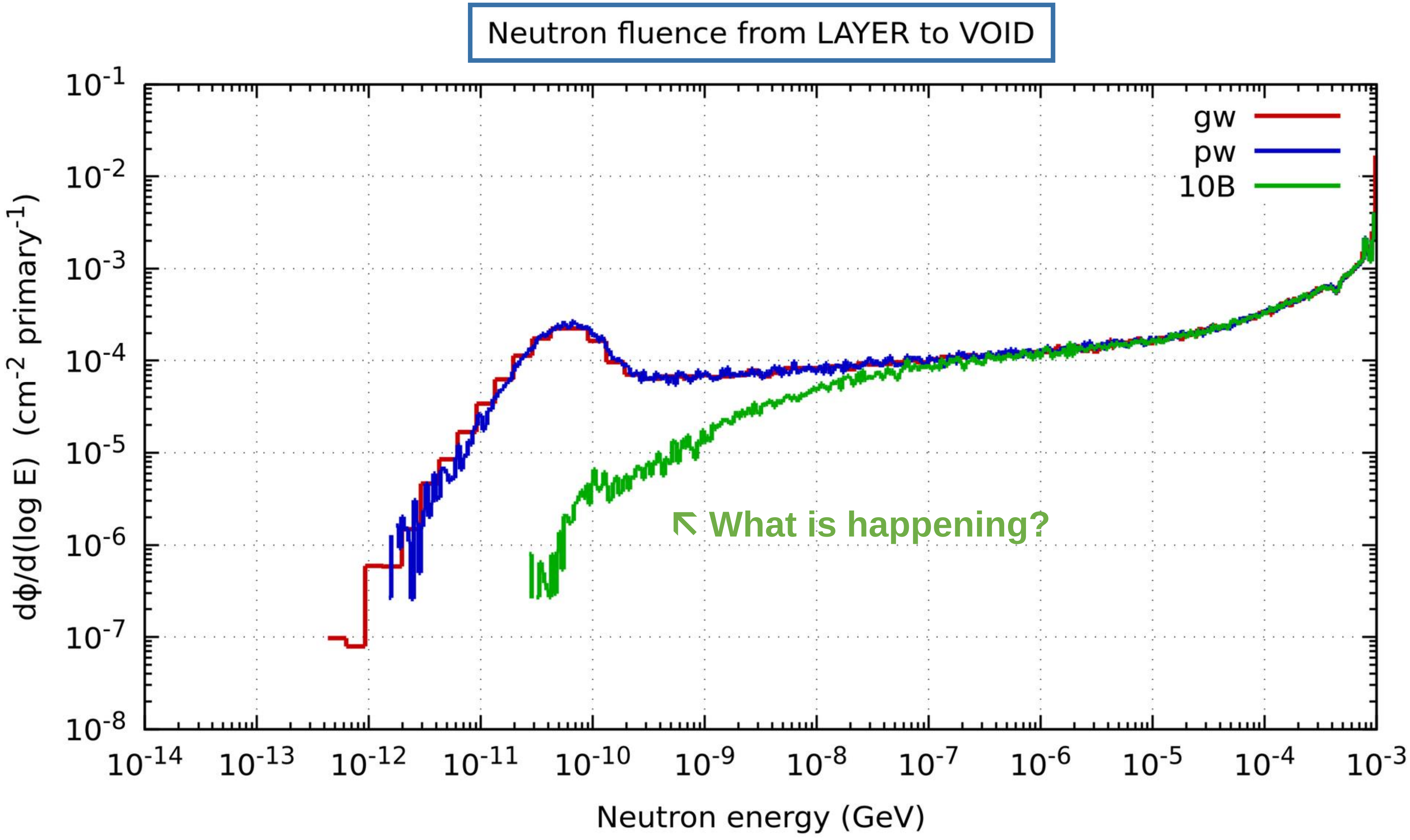
- What happened? Hint: slides of the first part of the lecture….

# 02 – Thin layer of $^{10}B$ – Results

Neutron fluence in H2O



# 02 - Thin layer of $^{10}$B - Results



# 03 – Thin layer of Cd

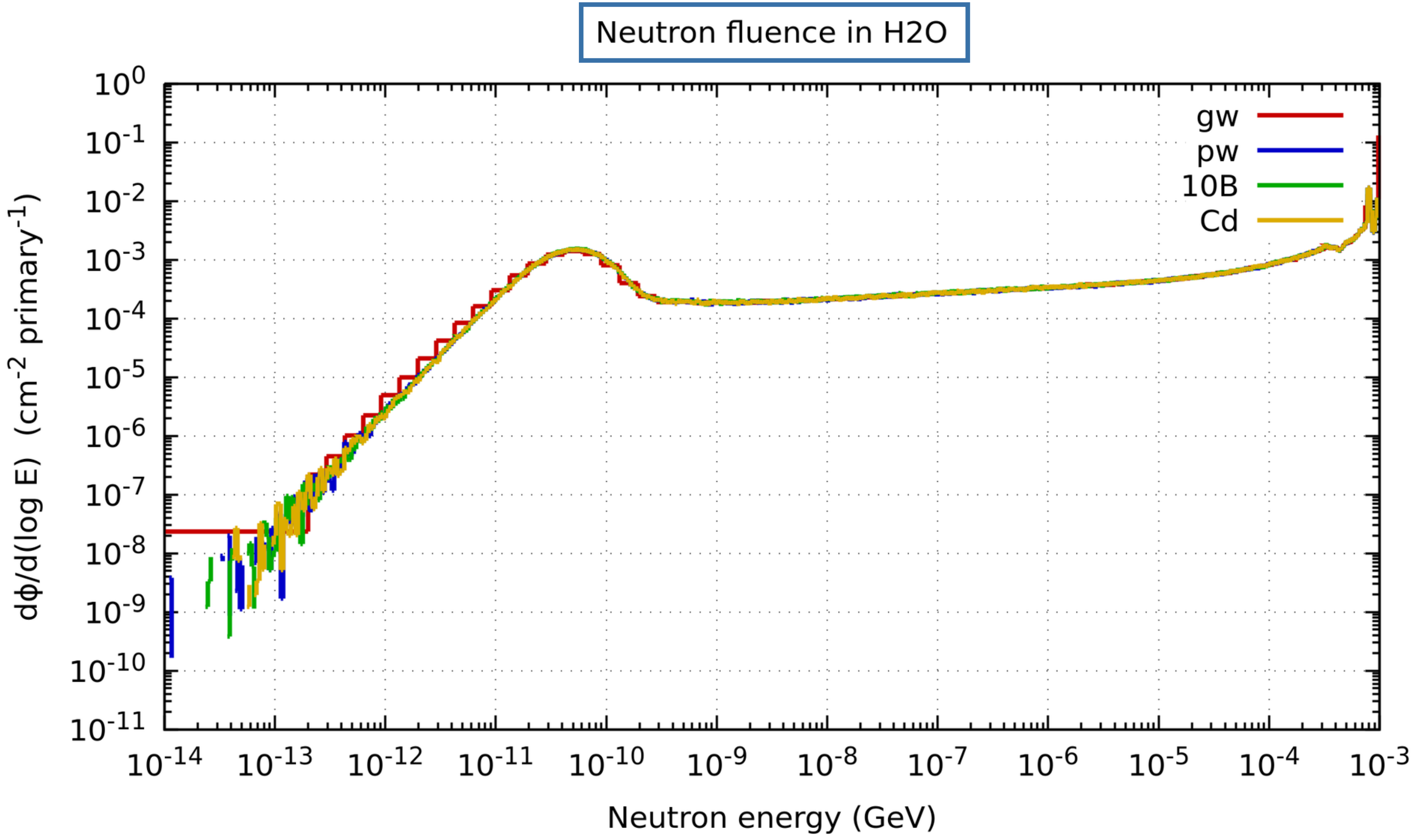
- Conditionally to the `Cd` preprocessor variable being active:
  - Material `CADMIUM` is assigned to the 100 µm `LAYER` region
  - Note the **`MATERIAL`** card defining the Cd material with natural composition

- Add a new `run/Cd` with both `pw` and `Cd` variables active (all other variables off)

- Run! Process!
- Add the n fluences to the two plots. Maybe move the plot key to the bottom (too crowded)

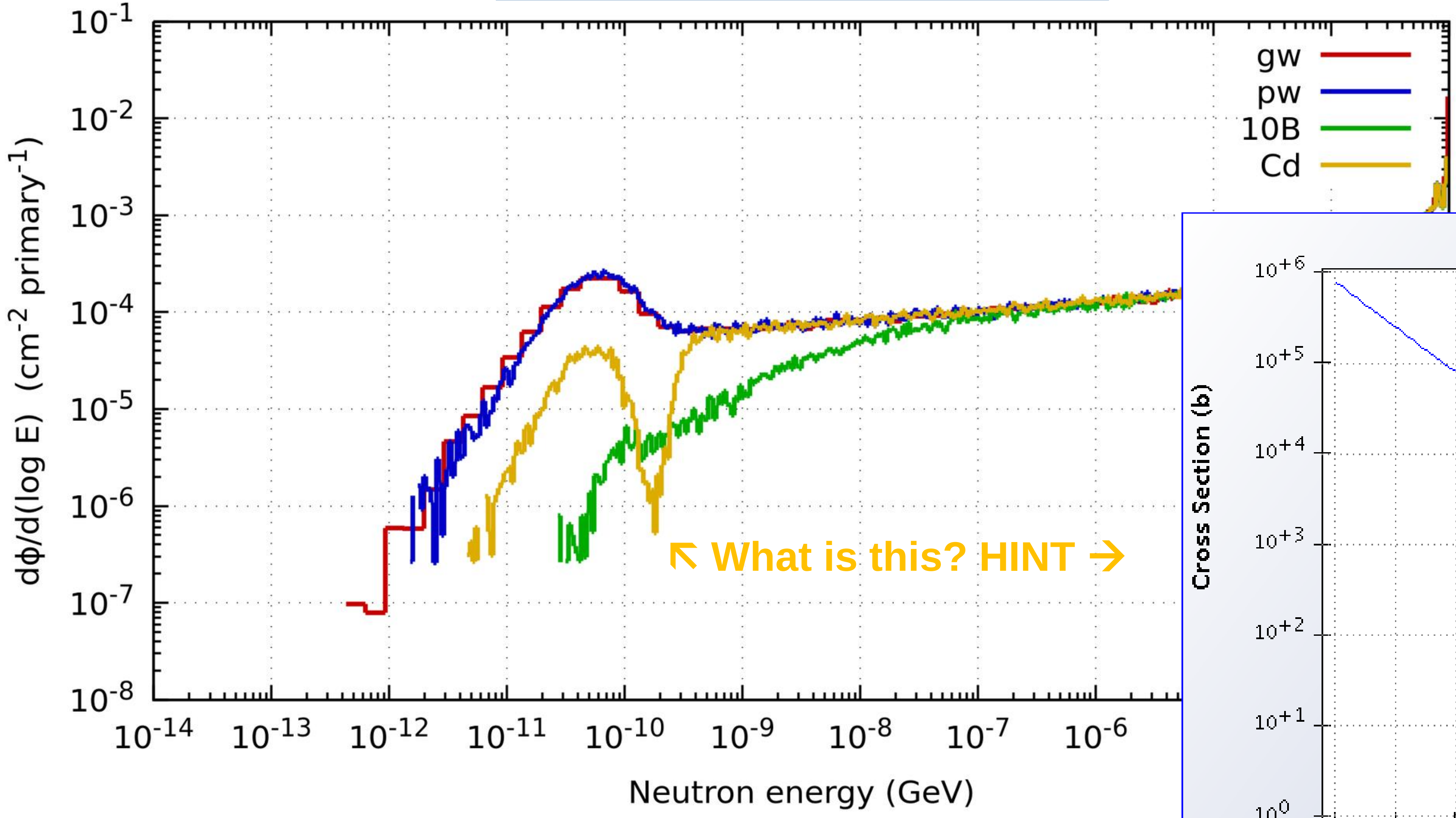
- What happened? Hint: slides of the first part of the lecture….

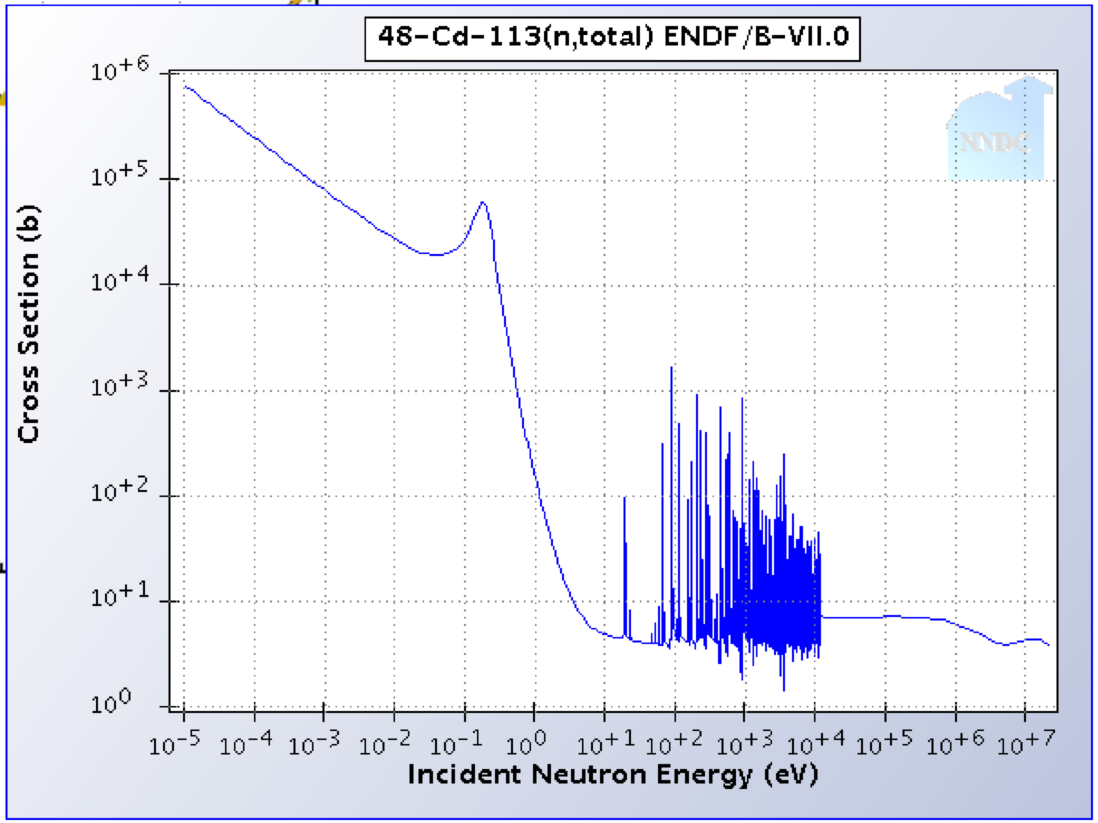
# 03 – Thin layer of Cd – Results



# 03 – Thin layer of Cd – Results

Neutron fluence from LAYER to VOID



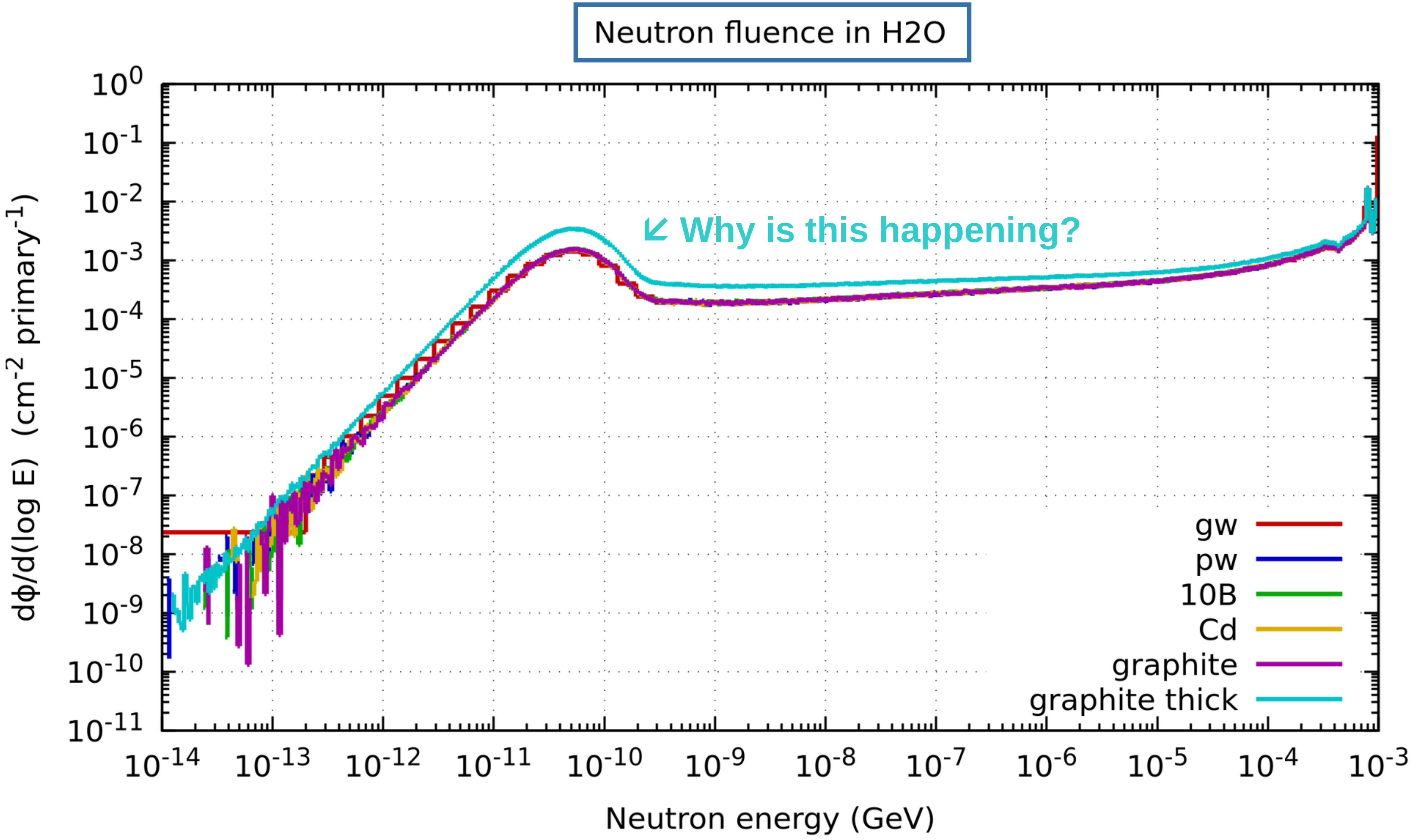
# 04 – Thick layer of graphite

- Conditionally to the preprocessor variable `graphite` being active:
  - The `LAYER` material is set to `CARBON`
  - Change the thickness of `LAYER` to 5 cm; you can accomplish this by use of a pre-processor directive in the geometry definition like this:

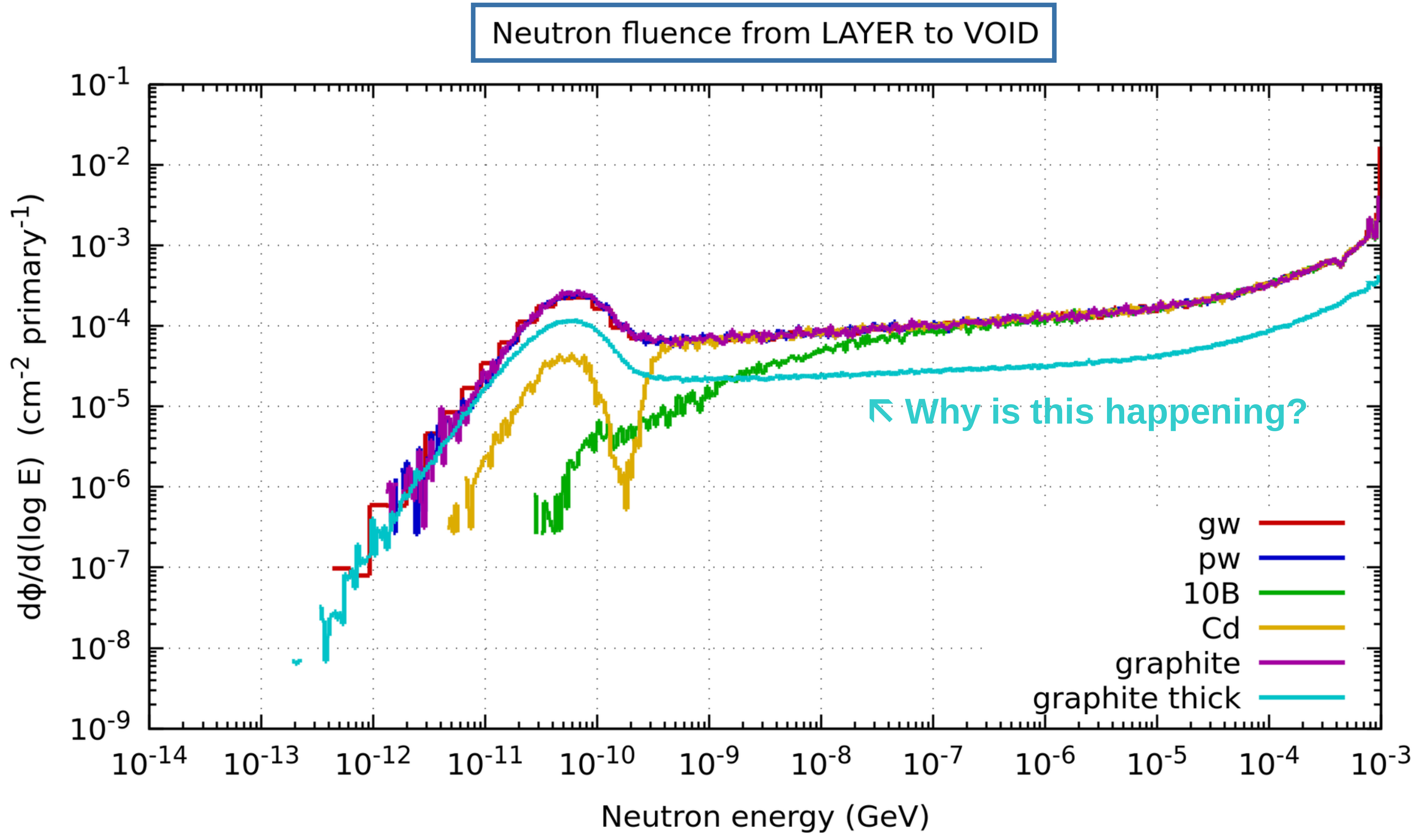
```
#if graphite
        R(sph3) = 10
#else
        R(sph3) = 5*cm + 100*um
#endif
```

- Add a new `run/graphite` run with `pw` and `graphite` active
- Run! Process!
- Add the n fluences to the two plots
- What happened?

# 04 – Thick layer of graphite - Results



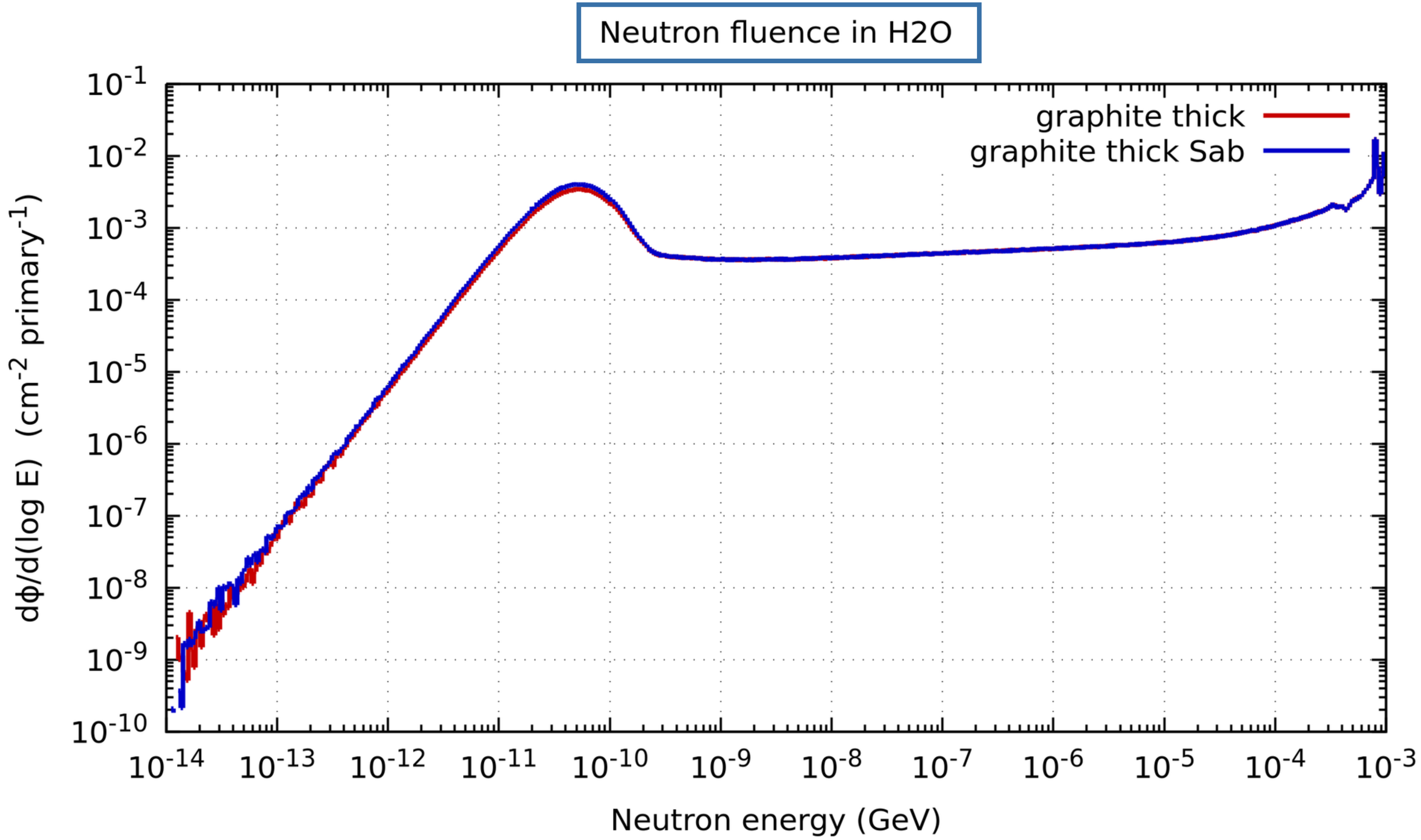
# 04 – Thick layer of graphite - Results



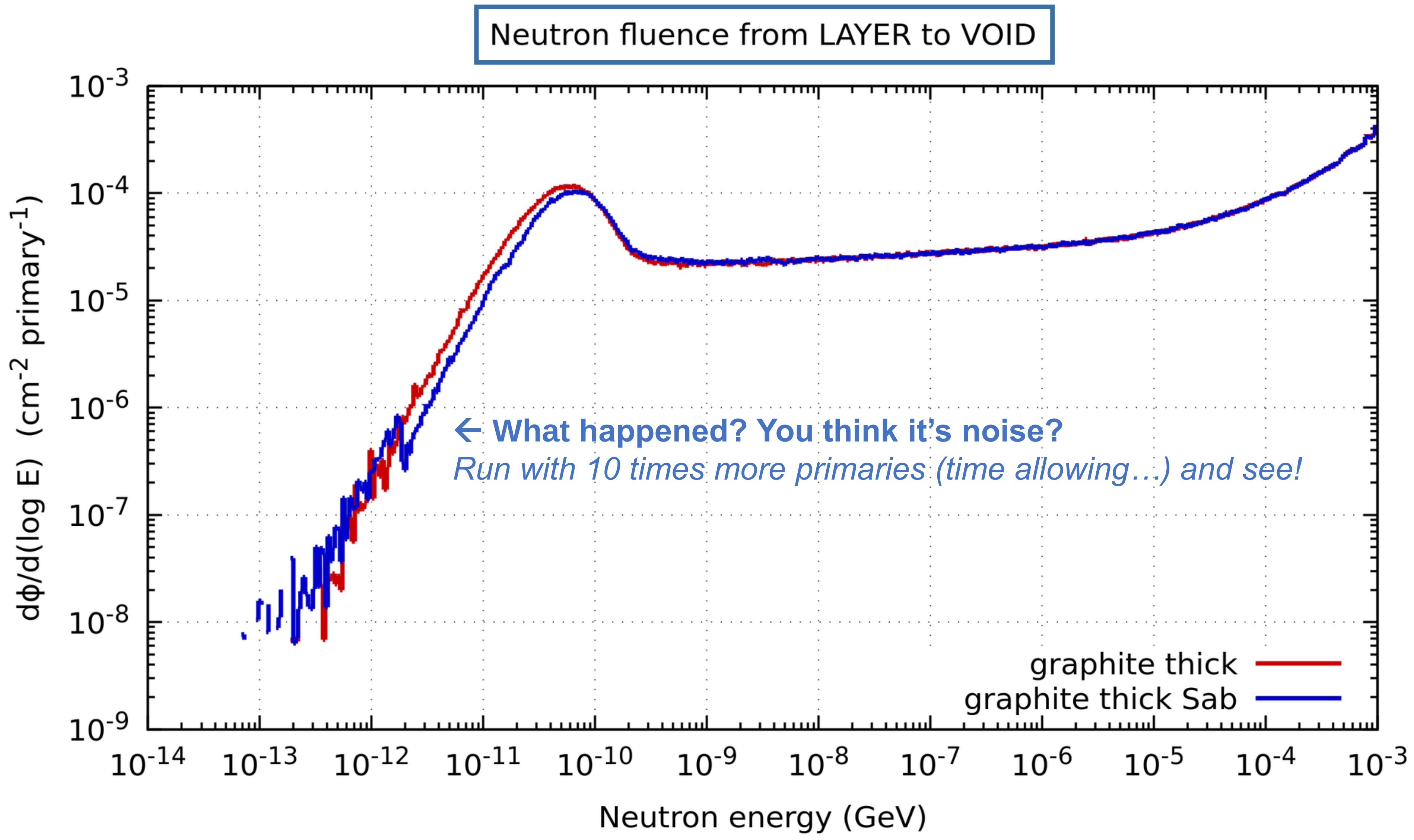
# 05 – Binding effects (optional)

- Conditional to the preprocessor variable `binding` (as well as `pw`) being active:
  - Add a **`LOW-PWXS`** card to select graphite binding environment for `CARBON`
- Add `run/graphitebinding` with `pw`, `graphite`, and `binding` active
- Run! Process!
- Add the n fluences to the two plots (maybe untick the other plots to resolve better)
- What happened?

# 05 – Binding effects – Results



# 05 – Binding effects – Results



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