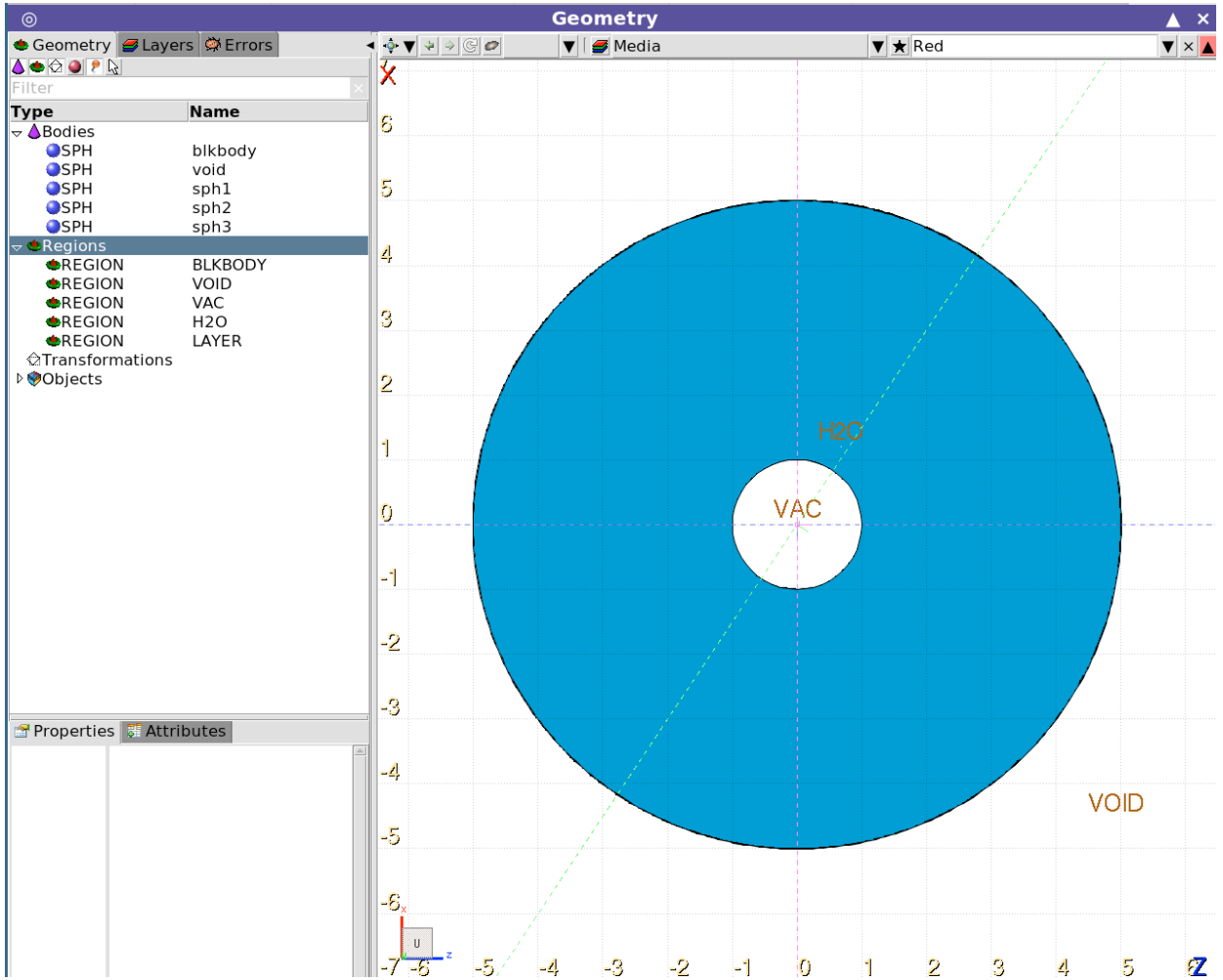
Exercise: low-energy neutronics

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)
- Gain further practice with pre-processor directives
- Bonus (time allowing): examine crystal binding effects on the neutron fluence
- NB: for maximum comfort, we have .flair files as snapshots at the end of every slide…

01 – Geometry (provided)



- Consists of three sphere bodies:
  - `sph1`, R = 1 cm
  - `sph2`, R = 5 cm
  - `sph3`, R = 5 cm + 100 um
- 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 directives, LOW-PWXS, scoring (provided)

- Source:

```
Define the beam characteristics
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 to `pw`:

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

- Scoring:

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

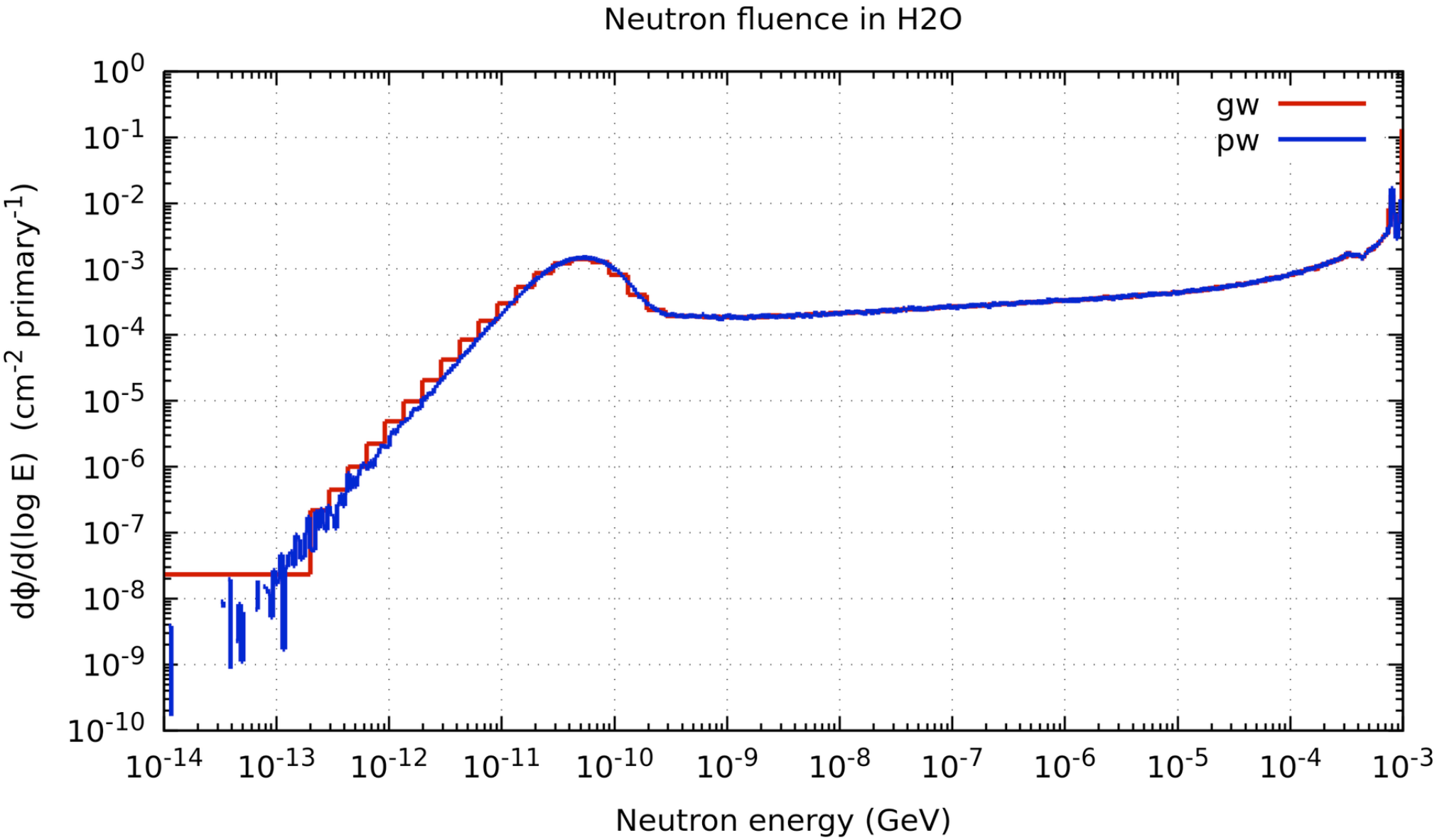
01 - Run, process, and plot

- 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
  - Set linewidth 2, Xmin=1e-14, xmax=1e-3
  - 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 gourmets:

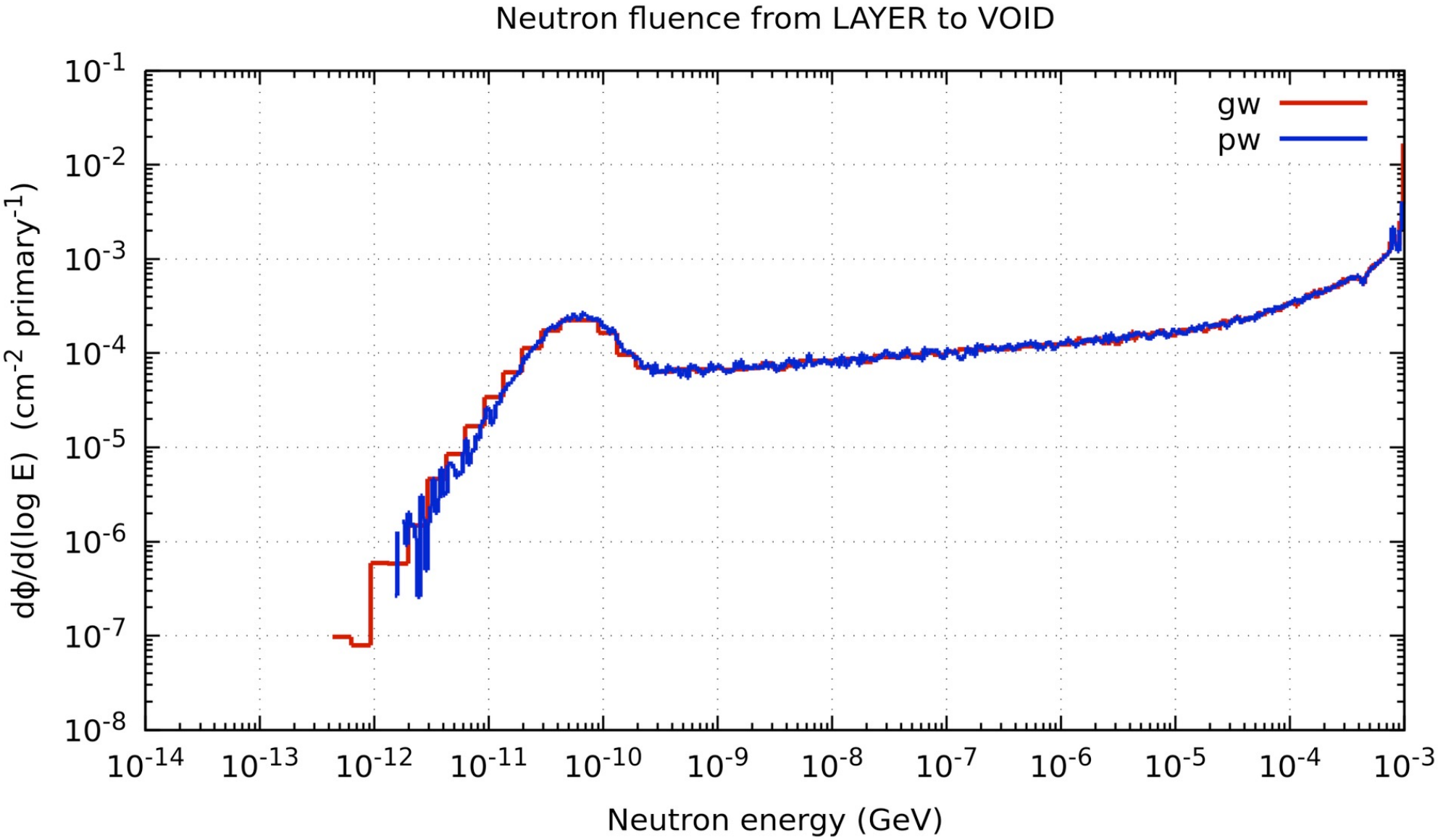
```
se xtics 10;se ytics 10;set grid;
se form xy “10^{%L}”
```

- Can you explain the spectral differences?
- All subsequent runs are with pointwise interactions (`pw` active)

01 - Solutions



01 - Solutions



02 - Thin layer of ^{10}B

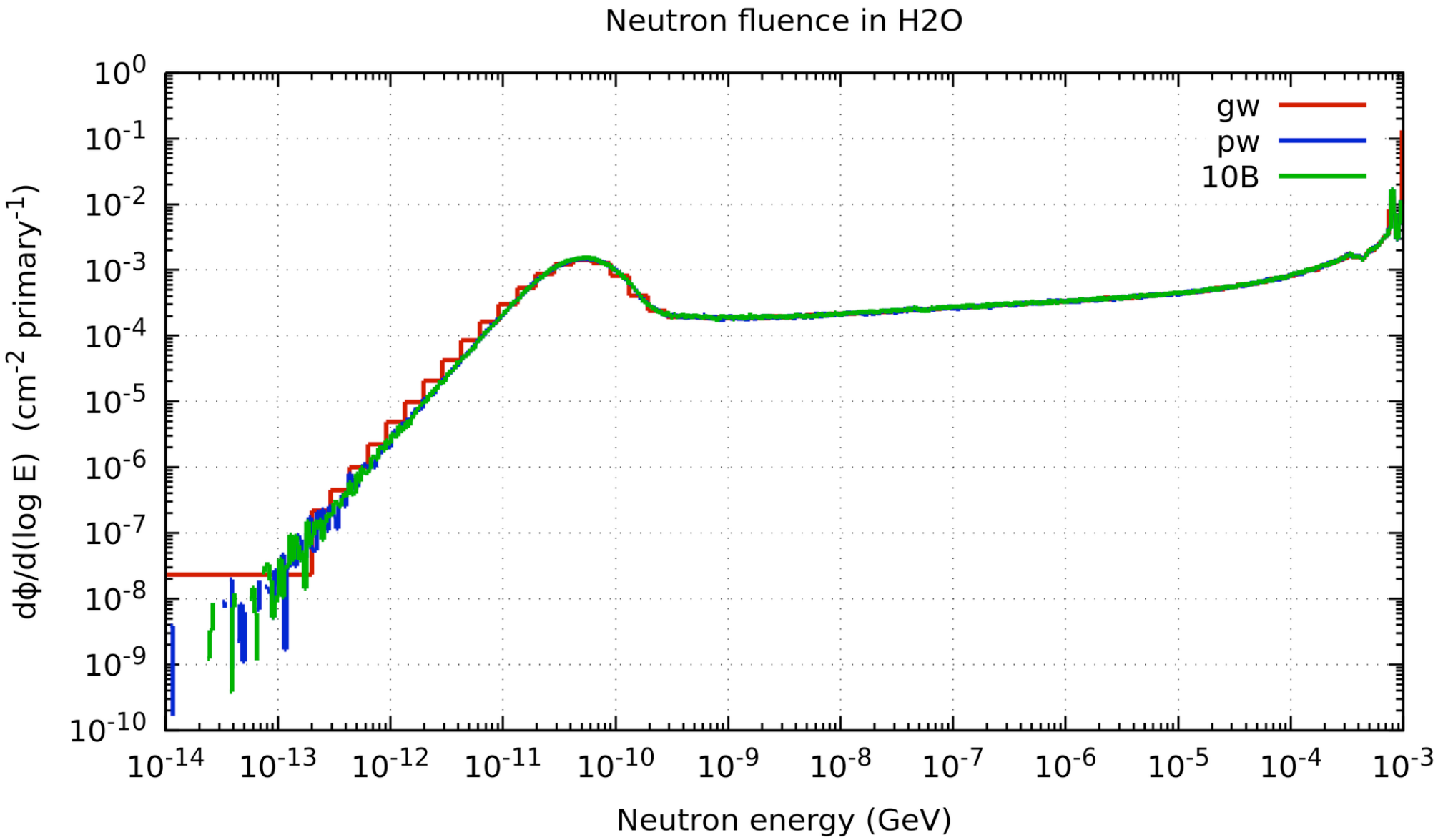
- Conditionally to the `10B` preprocessor variable being active:
  - Add a new material card with name `BORON10` (isotopically pure ^{10}B, not natural composition!)
  - Assign `BORON10` to the 100 um `LAYER` region

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

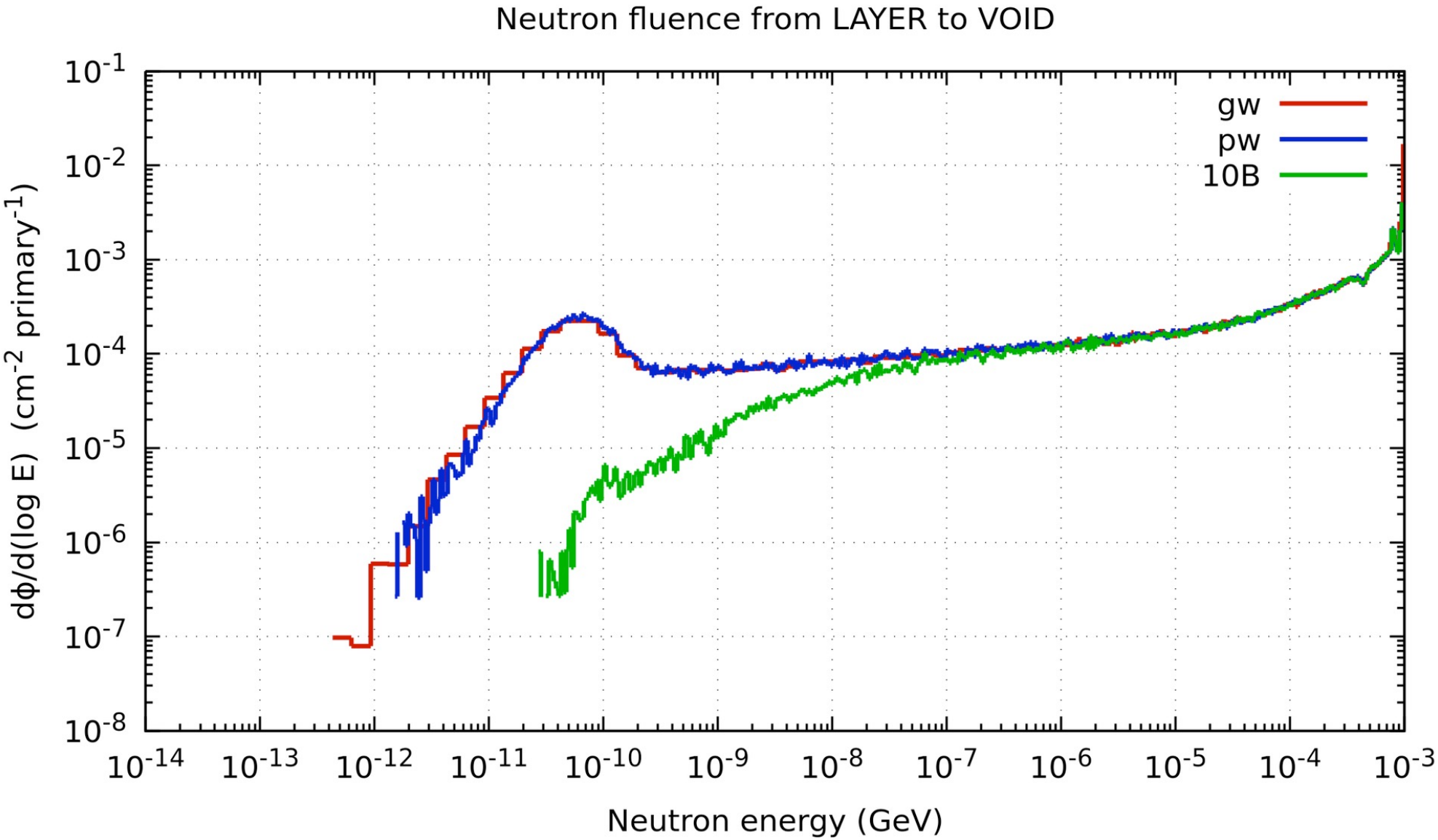
- Run!
- Process!
- Add the n fluences to the two plots

- What happened? Hint: slides of the first 1/3 of the lecture….

02 - Solutions



02 - Solutions



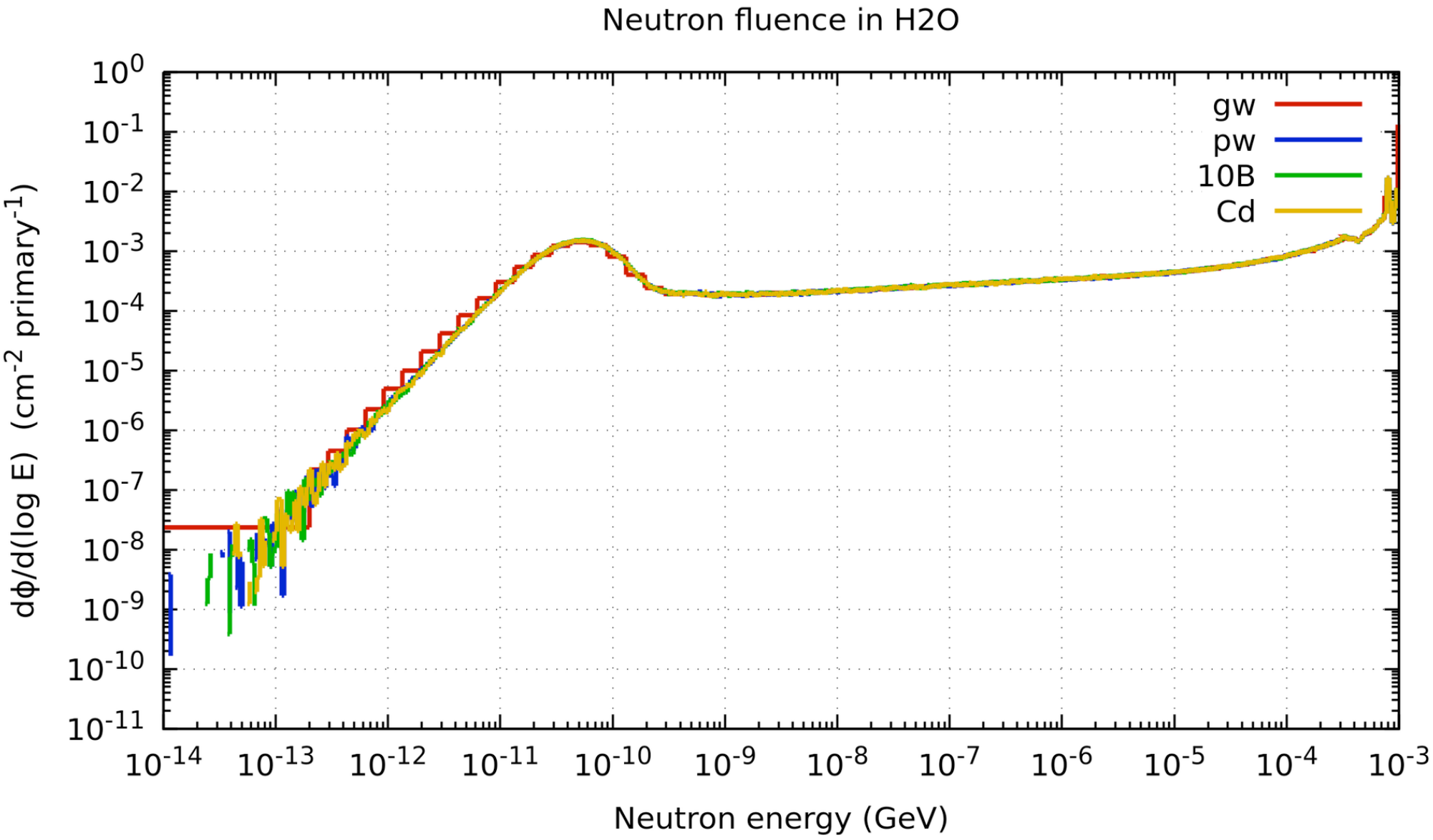
03 - Thin layer of Cd

- Conditionally to the Cd preprocessor variable being active:
  - Add a `MATERIAL` card for `Cd` in natural composition from the Flair database
  - Assign `CADMIUM` to the 100 um `LAYER` region
- Add a new `run/Cd` with both `pw` and `Cd` variables active (all other variables off)

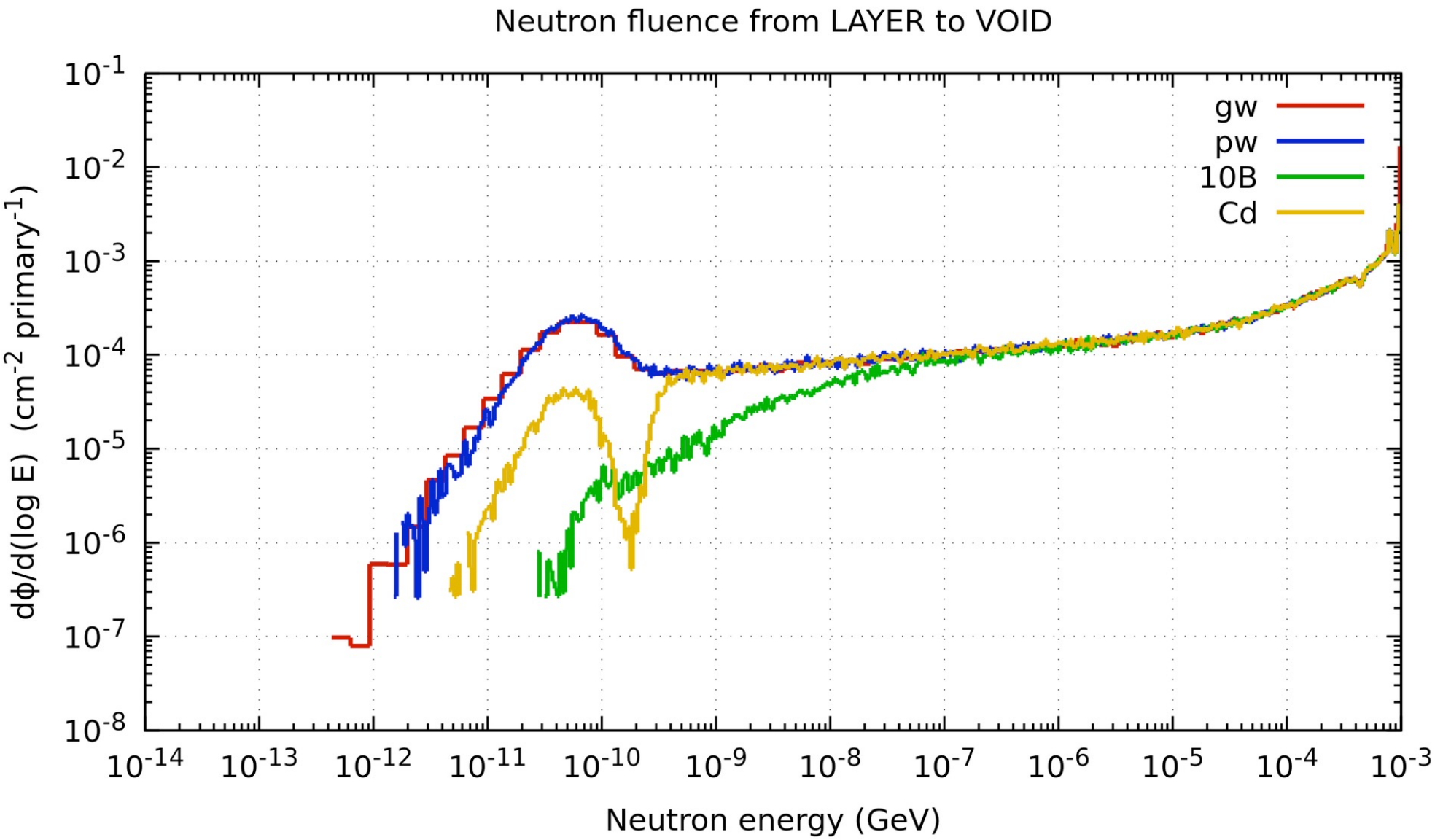
- Run!
- Process!
- Add the n fluences to the two plots. Maybe move the plot key to the bottom (too crowded)

- What happened? Hint: slides of the first 1/3 of the lecture….

03 - Solutions



03 - Solutions



04 - Thick layer of graphite

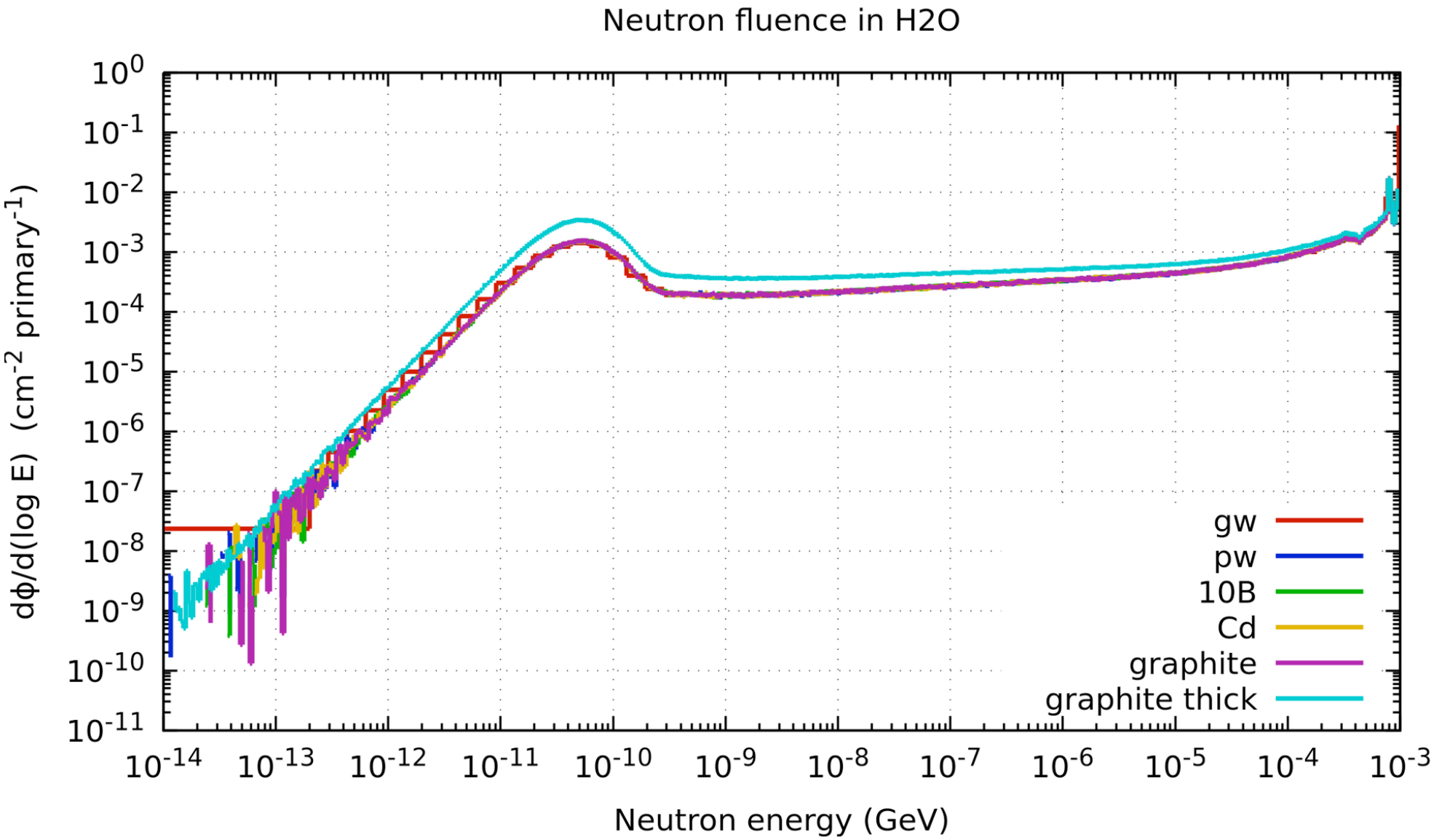
- Conditionally to the preprocessor variable `graphite` being active:
  - Change the thickness of `LAYER` to 5 cm
  - Set the `LAYER` material to `CARBON`

- Add a new `run/graphite` run with `pw` and `graphite` active

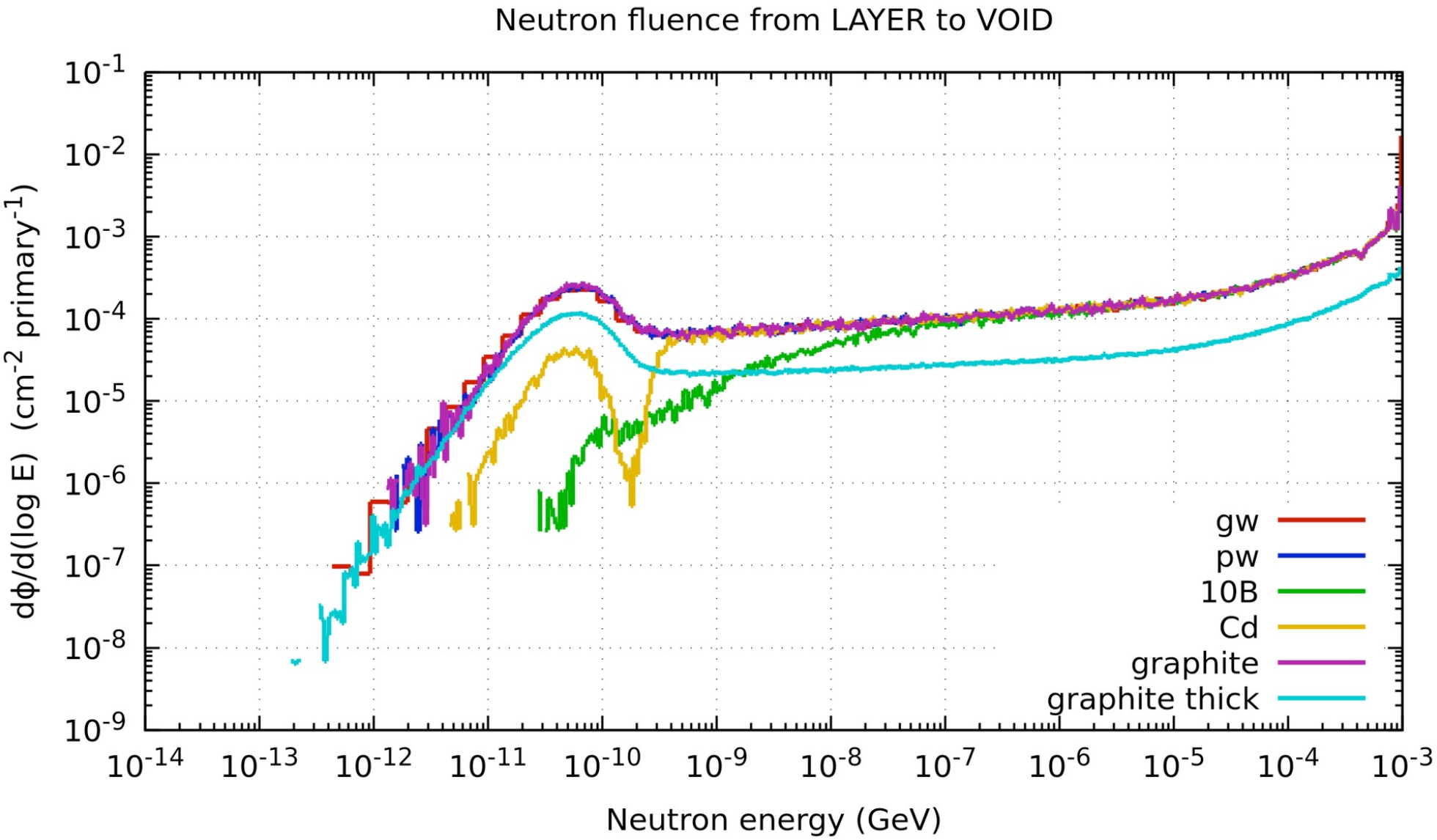
- Run!
- Process!
- Add the n fluences to the two plots

- What happened?

04 - Solutions



04 - Solutions



05 - Binding effects

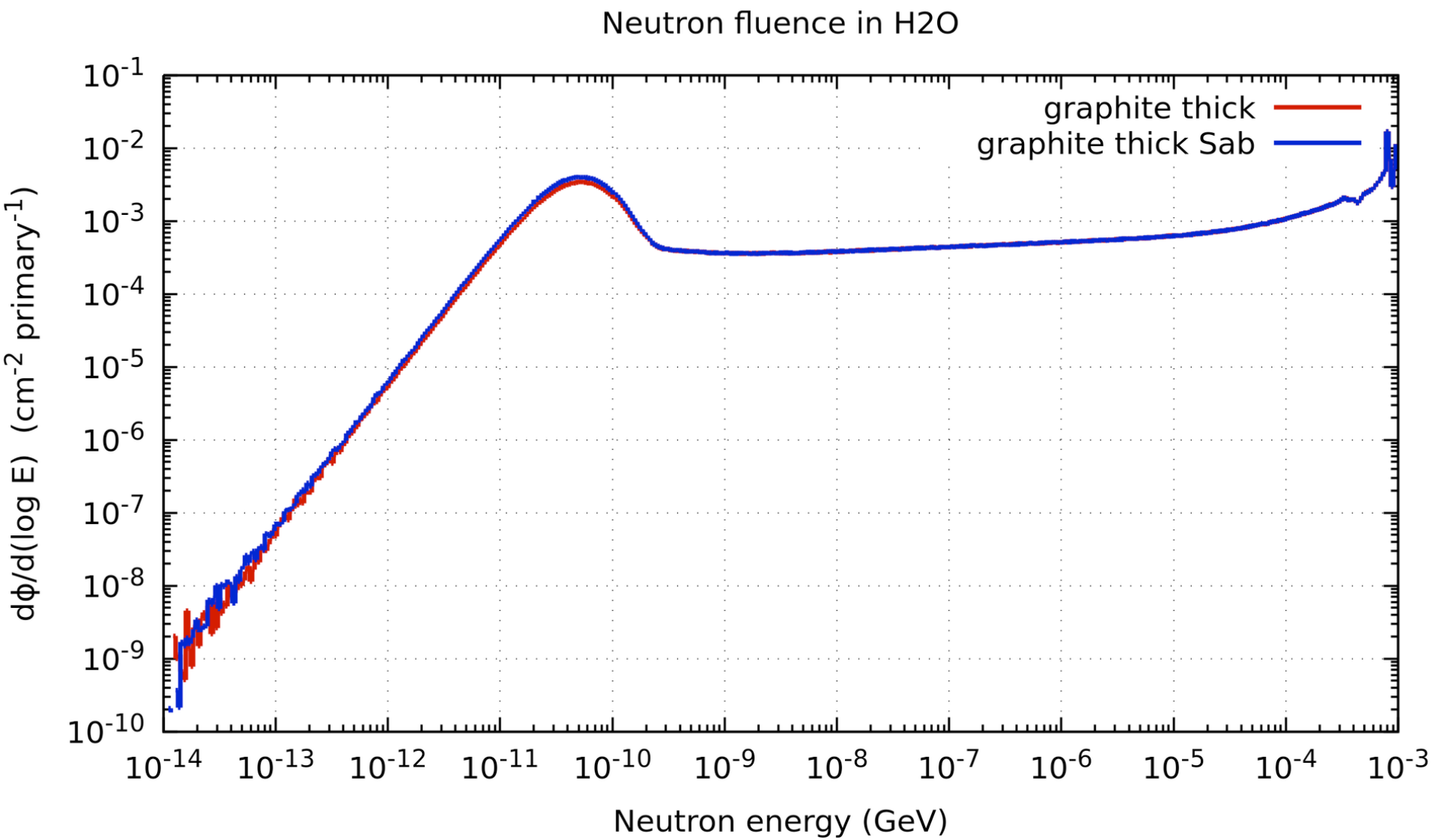
- Conditional to the preprocessor variable `binding` (as well as `pw`) being active:
  - Use the `LOW-PWXS` to select graphite binding environment for (all isotopes of) `CARBON`

- Add `run/graphitebinding` with `pw`, `graphite`, and `binding` active

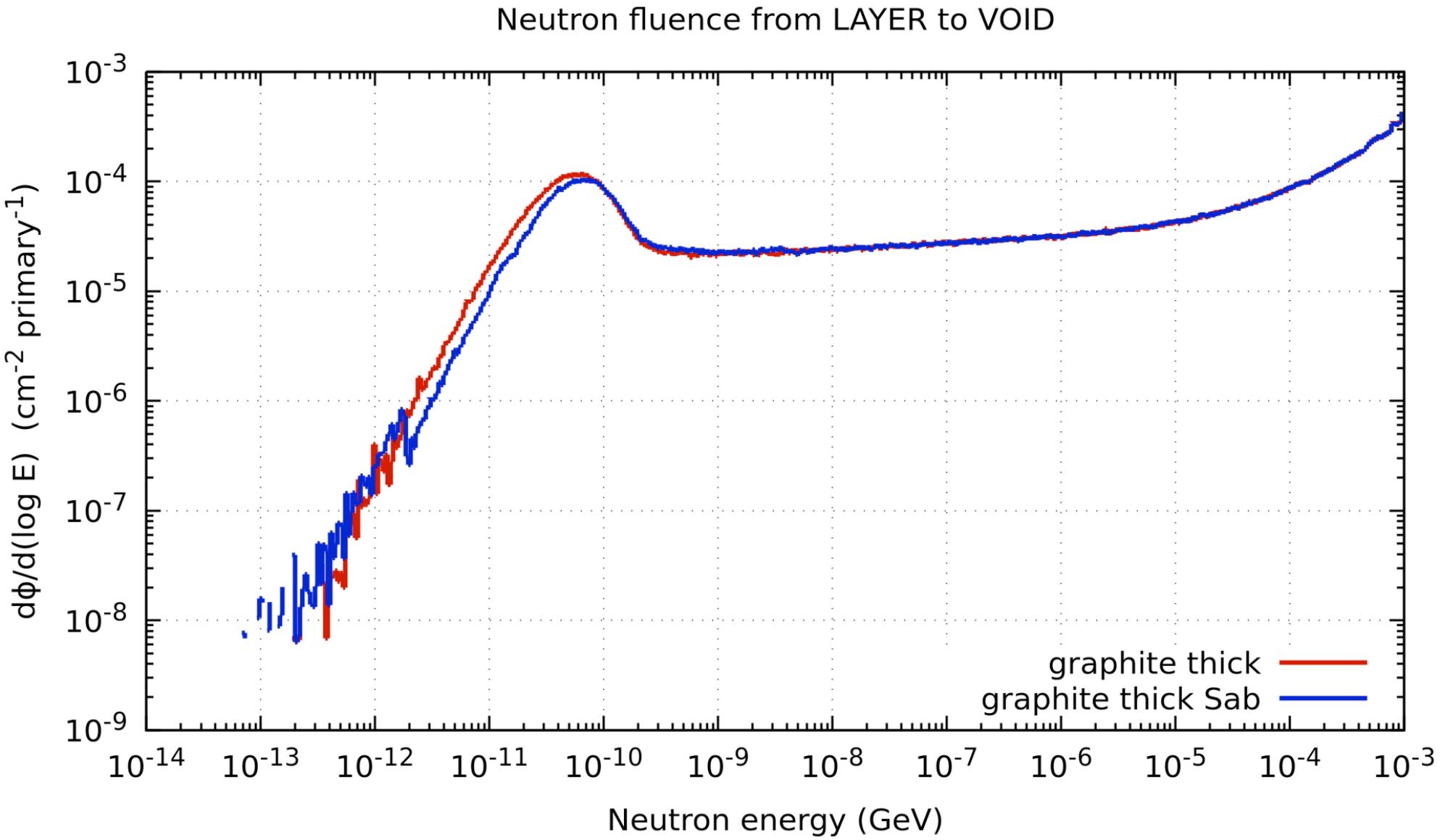
- Run!
- Process!
- Add the n fluences to the two plots (maybe untick the rest of plots to resolve better)

- What happened? You think it's noise?
  Run with 10 times more primaries (time allowing…) and see!

05 - Solutions



05 - Solutions

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