Detectors: ^{3}He and CCD's

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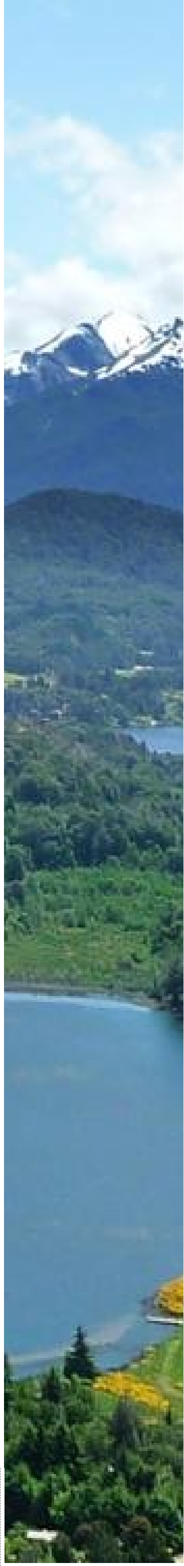
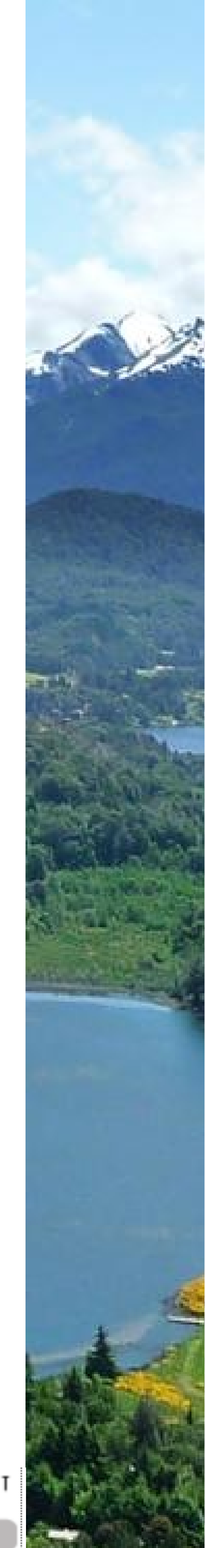
Detectors

- A bit of theory
- A small Gas detector
- Effect of the housing (background)
- CCD scintillator

Disclaimer: in case of errors and uncertainties, please correct me...



Detectors: Introduction

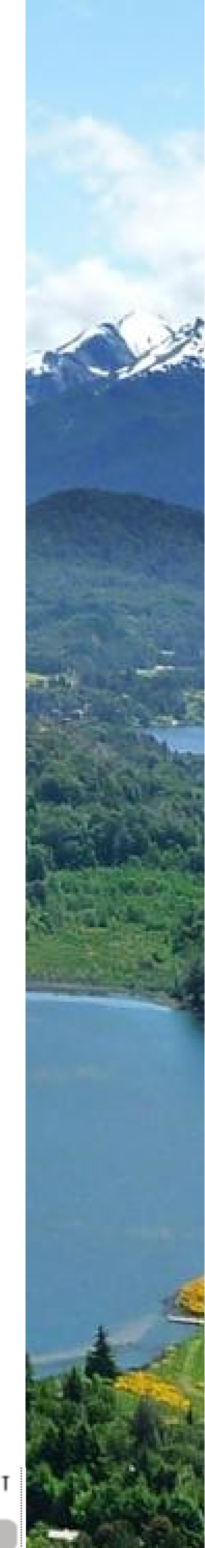


- Simple ideal detectors are usually part of any simulation. We call them '*monitors*'. Efficiency is 100%. I personally use ***Monitor_nD***.
- **Gas detectors** use the absorption of *n* by e.g. ^{3}He or ^{10}B. The capture reaction creates charges which drift in a high voltage field, and are collected by wires, raising an electrical signal.
- **Scintillator** detectors also use capture, e.g. by ^{6}Li, but collect photons in a PM.
- **Semiconductor** detectors: insert Li in Si. Work as a diode. *Not considered here*.

Detectors: ^{3}He

- Capture: n + ^{3}He → ^{3}H + ^{1}H + 765 keV;
- Helium is mixed with a stopping gas in *E*-field. Energy is dissipated in the 'stop' gas (CF_4, CO_2...). Fragments drift.
- He detectors have e.g. 70-90% detection efficiency. Low sensitivity to γ. Fast (kHz).
- Cost: 10 k€/m^{2}.

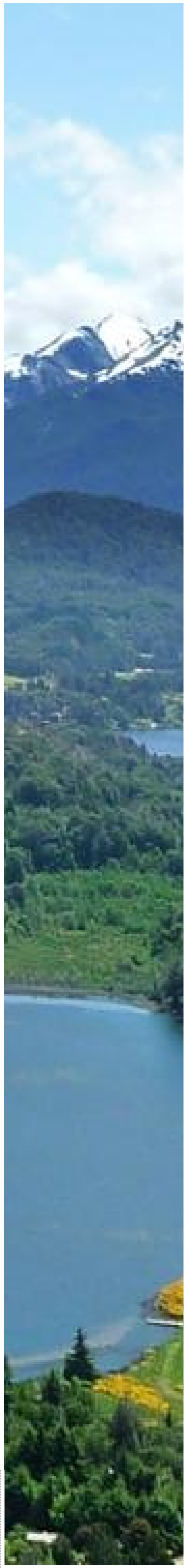
$$\sigma = 5333 \frac{\lambda}{1.8}$$



Detectors: ^{6}Li

- Capture: n + ^{6}Li → ^{3}H + ^{4}He + 4.79 MeV
- Lithium is trapped in a matrix, and secondary photons are collected into a photo-multiplier.
- Scintillation efficiency for ZnS(Ag)-LiF is 9.2% and highly sensitive to γ. High positional accuracy (50 µm). Slow response (Hz).
- Cost: 3 k€/400cm² (CCD, with USB)

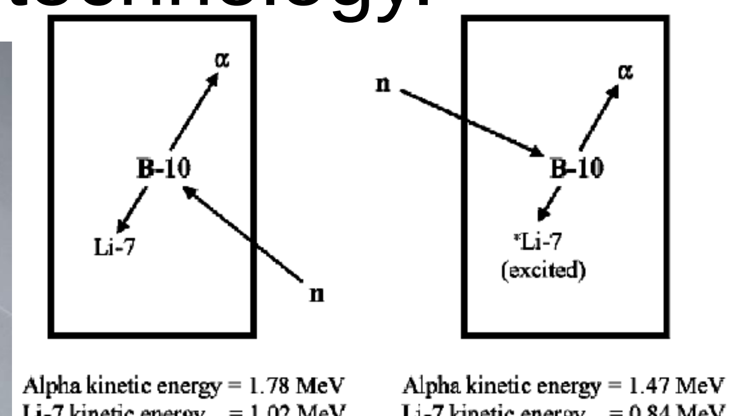
$$\sigma = 940 \frac{\lambda}{1.8}$$



Detectors: ^{10}B

- Capture: n + ^{10}B → ^{7}Li + ^{4}He + (2.3;2.8) MeV
- Boron is either as BF3 gas (toxic), or as a thin µm layer and drift gas in E-field. Fragments energy is dissipated in the gas (BF3, CF4).
- B detectors have e.g. 30-40% detection efficiency. Low sensitivity to γ. Fast (kHz).
- Cost: 10 k€/m^2, depends on technology.

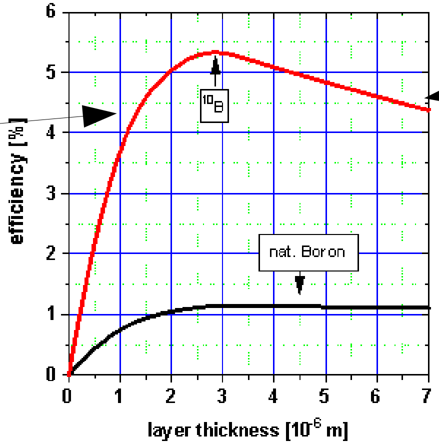
$$\sigma = 3835 \frac{\lambda}{1.8}$$



Detector efficiency

- Efficiency: $\epsilon = 1 - e^{-N\sigma t}$
- Where
  - σ: absorption cross section
  - N: number density of absorber, 2.7×10^{19} $cm^{-3} \cdot atm^{-1}$ in a gas
  - t: thickness in cm
- The fragments drift determines the spatial resolution.

Exp efficiency

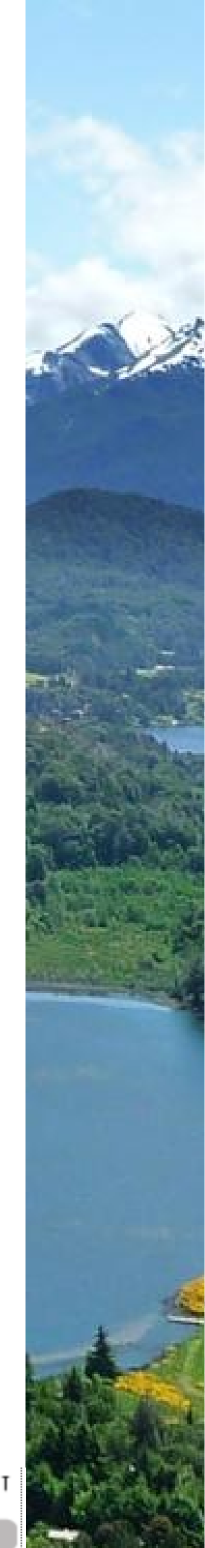


Charges are trapped (wall effect)

Simple detectors in McStas

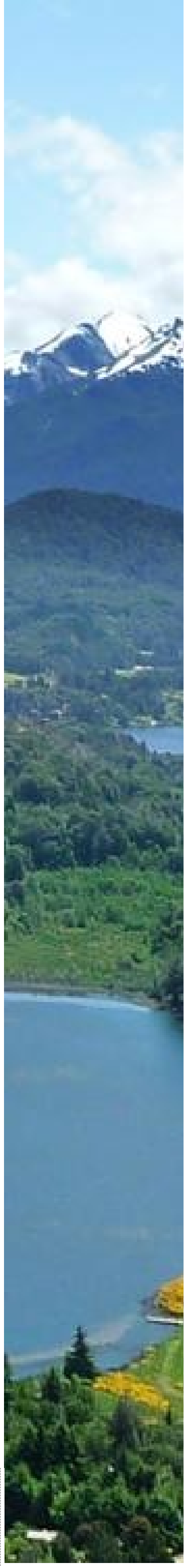
- Weight the neutron event with the *exponential* efficiency law.
- Done either in a dedicated component, e.g.
  - Monitor_nD(options="3He_pressure=3")
  - PSD_monitor_psf_eff(psf=1mm, k0=3.5, eff=0.5)
- Or in an EXTEND block

```
EXTEND %{ // N per cm3, T in cm, s_abs in barns
  p *= 1.0-exp(s_abs*2200/v*N/1e24*T*eff);
%}
```



Gas detectors in McStas

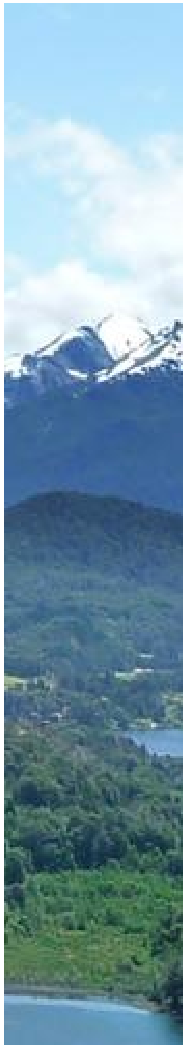
- The ***PSD_Detector*** component models the drift of charges in the stopping gas after capture. It also handles wall effects and parallax. Electrostatic lens correction can be added. Can generate histograms and event lists.
- All detectors can be enclosed in a 'housing' to model the effect of the Al or Fe container (produces background from Bragg and incoherent scattering).

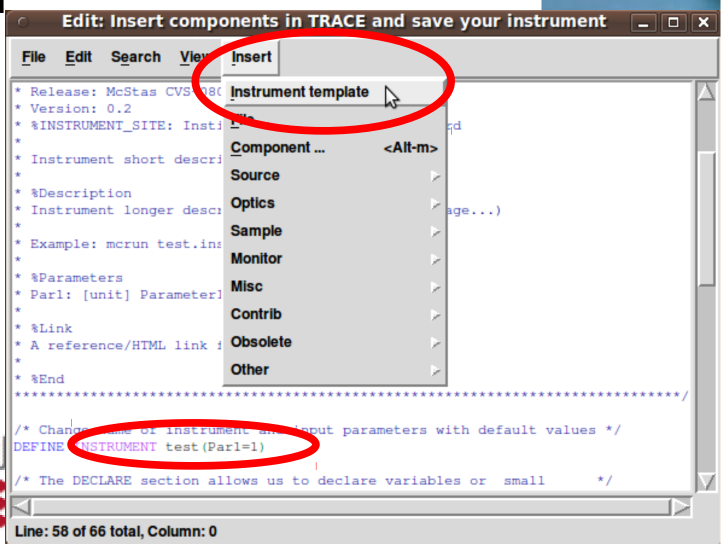


Detectors: Exercise 1: gas detector

Aim: simulate a multi-wire gas detector, and estimate its resolution.

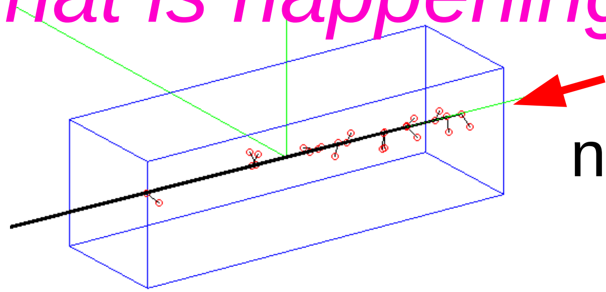
- Create a new Template instrument.
- Define an instrument **input parameter(***lambda=2* Å) to set the neutron wavelength.
- Insert a ***Source_simple****(radius*=0.1mm, focusing onto a 0.1x0.1 mm², with neutron wavelength=*lambda* and *dlambda=0.1* Å).

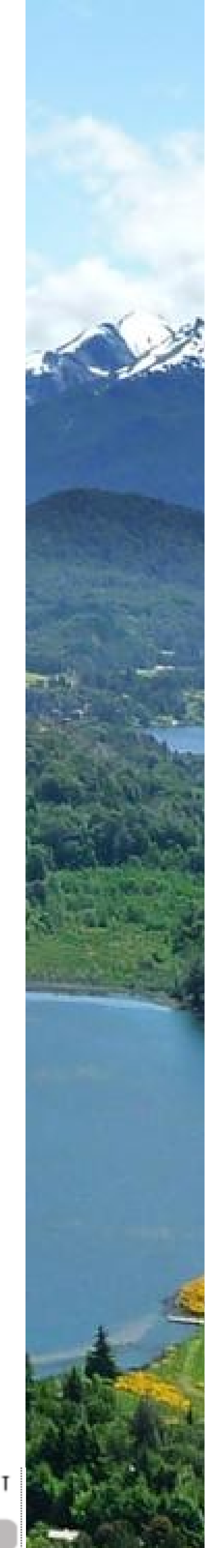




Detectors: Exercise 1: gas detector

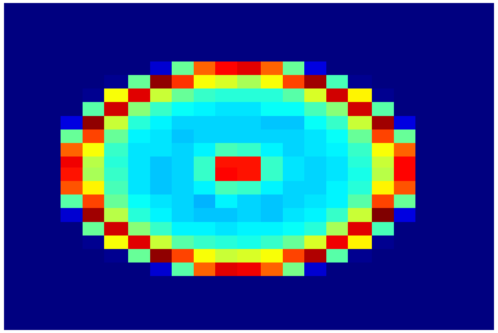
- Insert a **PSD_Detector** (contrib) at 2 m from PREVIOUS, with
  - size 2.6x2.6 cm², depth 2.5 cm
  - Converter="He3inHe.table" 5 bars
  - Stop gas="He3inCF4.table" 1 bar
- Save and **Run**. Use the **Trace** mode instead of *Simulate*.
- Click **Start** and look at neutron trajectories in the detector. *What is happening ?*

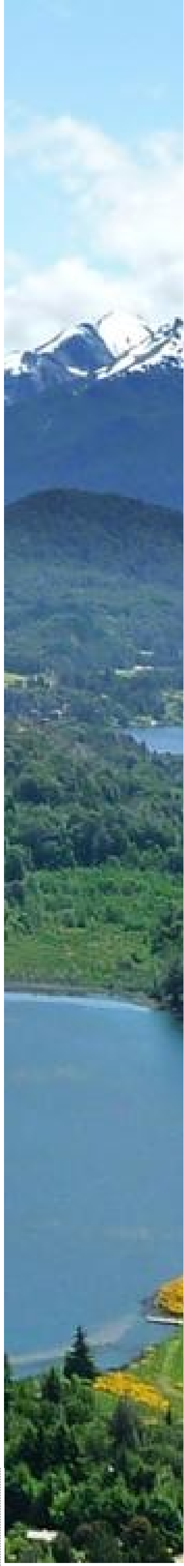




Detectors: Exercise 1: gas detector

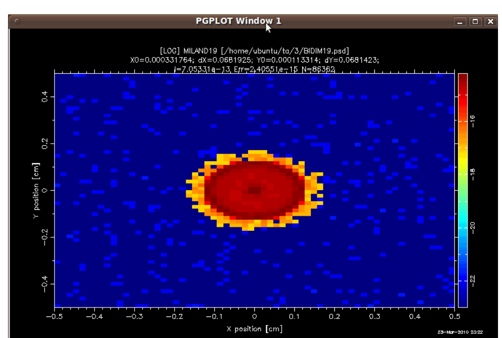
- Re-run, in **Simulate** mode with 1e6 neutron events, and determine the detector intrinsic spatial resolution (given by the size of the cloud of charges) at *lambda*=1, 2…10 Å.
- To measure the efficiency, insert a monitor between the source and the detector, and measure the ratio=detected/incoming at *lambda*=1, 2…10 Å.

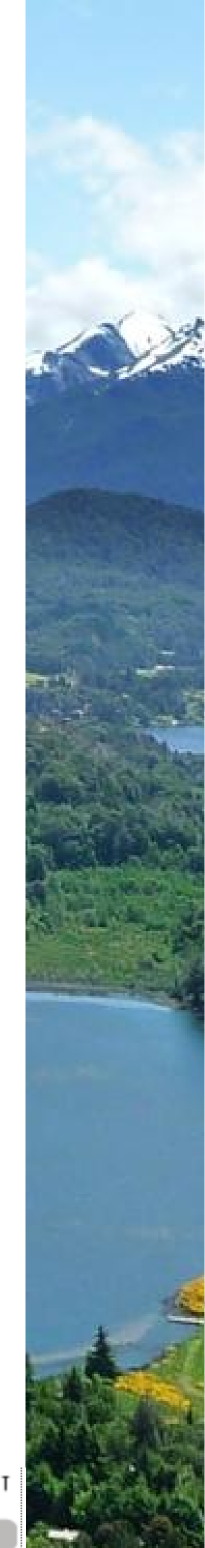




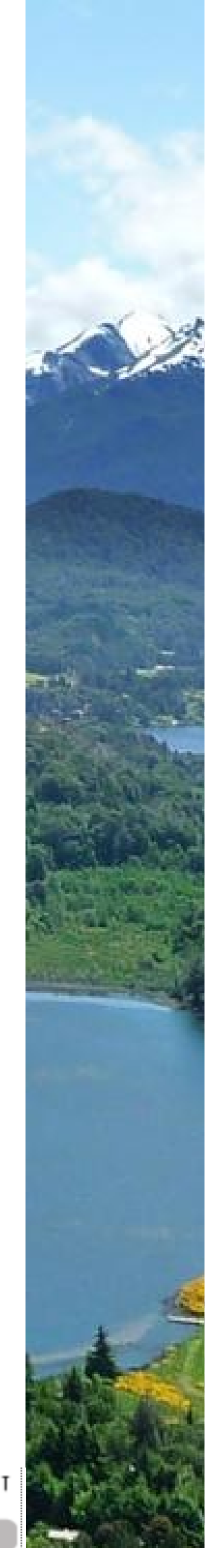
Detectors: Exercise 1: gas detector

- Add a 1 mm Al layer before the gas cell by inserting a **PowderN**(*reflections*="Al.laz"). This is to model the detector entry window.
- Run in **Trace** mode and check geometry and that no volume overlap exists (use VRML or PGPLOT).
- Run the simulation again at *lambda*=1 to 10 Å, with PGPLOT plotter. *Estimate the background from the entry window.*
- Repeat the same study with *reflections*= "Fe.laz" housing. *Can you comment ?*





Detectors: Exercise 1: gas detector

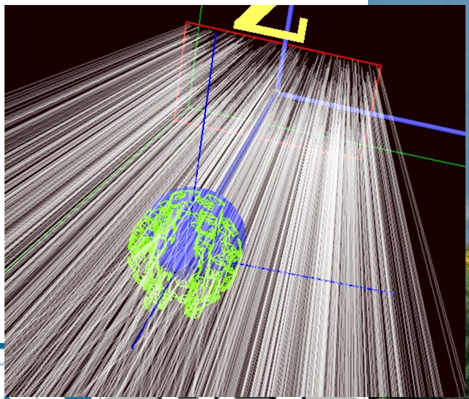


- Now a quick correction and a few comments.

Detectors: Exercise 2: CCD detector

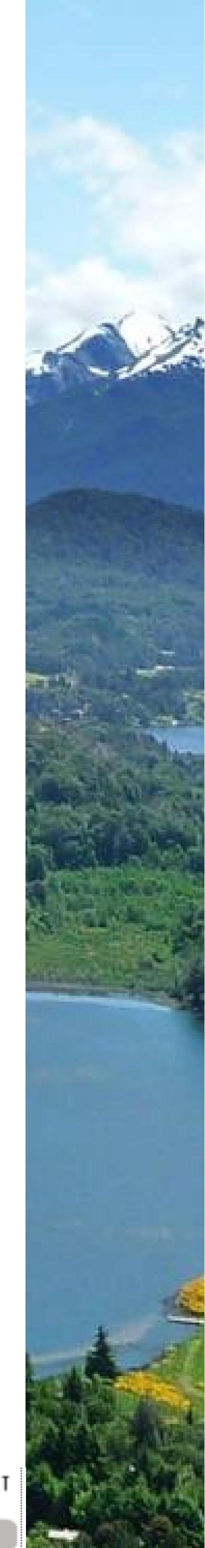
Aim: simulate a CCD/scintillator detector

- From the *Neutron site* menu, get the Templates/**Tomography** instrument.
- Click on the Edit button to show its description.
- Run in **Trace** with default parameters, with e.g. HTLM/VRML plotter, to check geometry.
- Run in **Simulate** mode, with PGPLOT plotter, σ_{abs}=5 (**warning**: use "quotes" around parameter *opts* value). Plot.



Detectors: Exercise 2: CCD detector

- The ZnS(Ag):LiF detector efficiency must be taken into account with N=1.18 10^{22} cm^{-3}, t=1 mm, $\sigma=940\ \lambda/1.8$, and a scintillation efficiency of 9.2%.
- The neutron velocity is $v=\sqrt{vx^2+vy^2+vz^2}$
- The ratio λ/1.8 is the same as 2200/v
- Derive the expression of the detector efficiency vs. neutron velocity (beware units, 1barn=10^{-24} cm^3).
- You should get a CCD efficiency of 9.7% at λ=1.8 Å.
- As a comparison, for 1 bar 3He and 1 cm thickness we get a theoretical 13.4%.

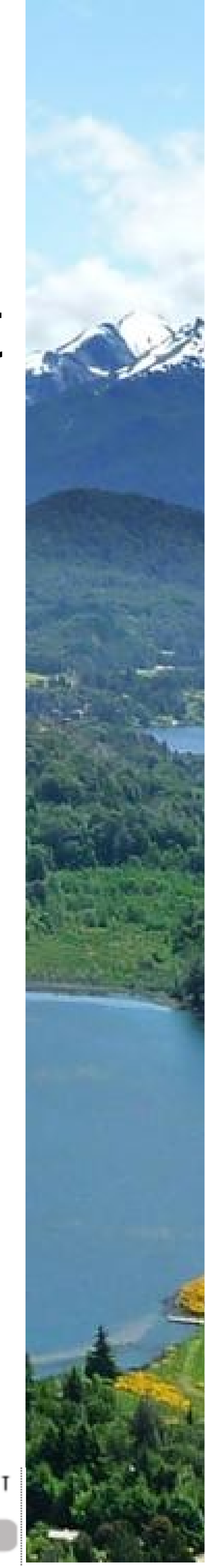


Detectors: Exercise 2: CCD detector

- After the last component '*monitor*' AT line, insert a block **EXTEND** %{

  %}

- This block can contain any C statements.
- In the EXTEND block, multiply the neutron weight 'p' with this efficiency.
- Create afterwards a new detector similar to 'monitor' with a different name, at 1cm distance.
- Measure the efficiency, as ratio=1st/2nd monitor at *lambda*=1, 2…10 Å.



Detectors: Exercise 2: CCD detector

- And the correction...