Update on Sensitivity Evaluation

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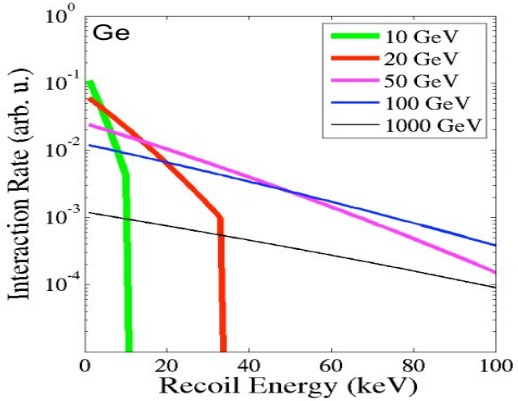
Goal and improvements

With the goal of evaluating the 3 σ sensitivity of the experiment, we realized that:

- The simulation of the fake experiments needs to take into account the composition of the detector all together

All the target elements must be simulated at the same time, considering relative percentage, density and cross section

- The escape velocity of the galaxy has a considerable effect for low masses searches



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Cross Section Calculation

- All the recoil spectra have to be revaluated including the escape velocity

- To assess the relative probability of which element recoils, the full rate calculation has to be performed

To check the consistency of the full calculation, we tried to eveluate the 90% CL at zero background

90% CL no Background

- We had a previous calculation and a code from Francesco and we used the Lewin-Smith paper (https://doi.org/10.1016/S0927-6505(96)00047-3)

Gave weird results
(wrong kinematic limits and unexpected features)

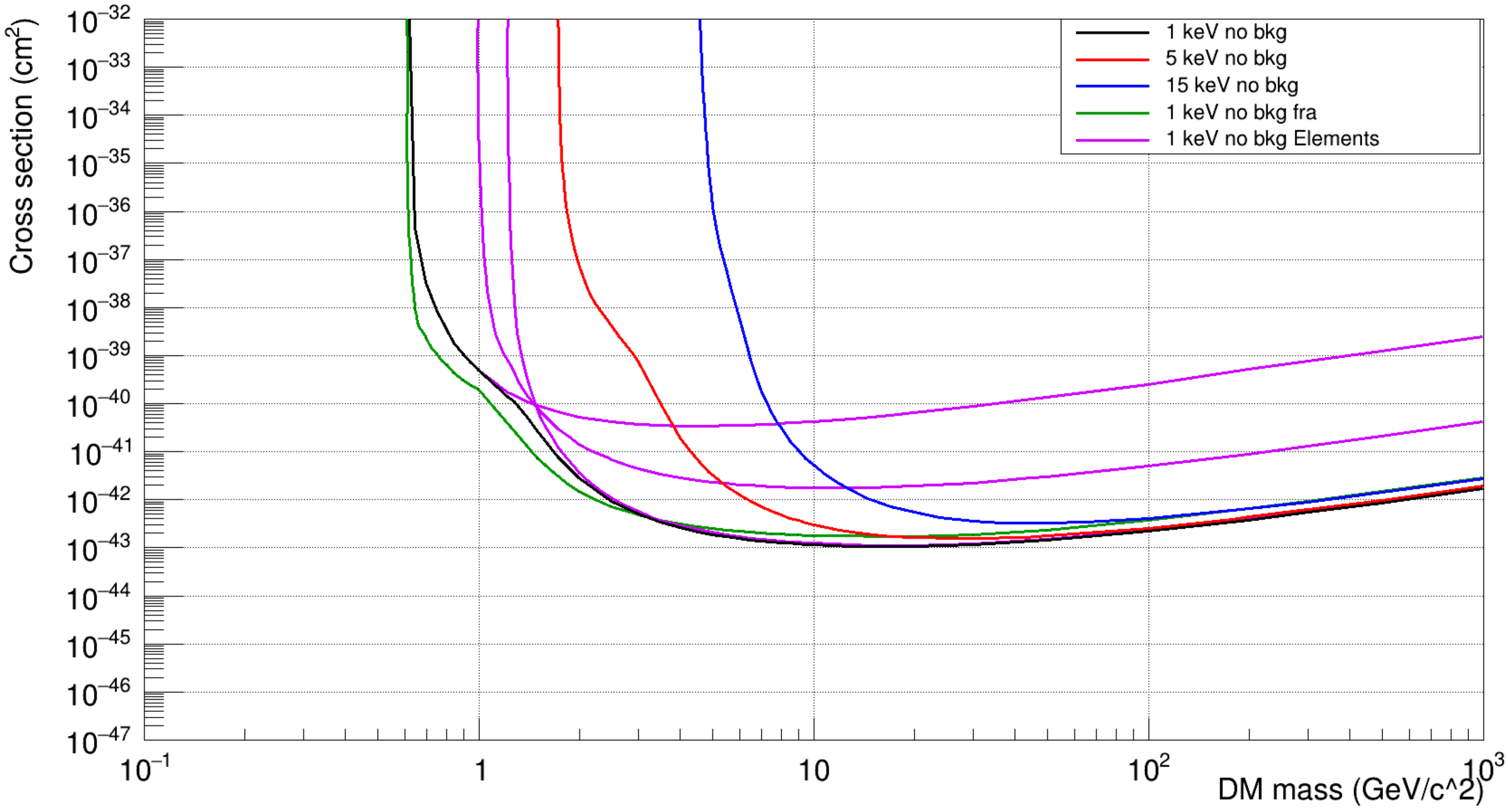
Wrong evaluation of erf function

- After repeating the calculation from scratch following the aforementioned paper, we reached the final version

$$\frac{dR_Z}{dE_R} = \frac{N_0}{A_M} N_Z \frac{2\rho_0}{m_\chi^2 r} \sigma_p A^2 F^2 \left(\frac{\mu_A}{\mu_p}\right)^2 \frac{k_0}{2v_e k_1} \times$$

$$\begin{cases} \left[\mathrm{erf}\left(\frac{v_{min}(E_R)+v_e}{v_0}\right) - \mathrm{erf}\left(\frac{v_{min}(E_R)-v_e}{v_0}\right) - \frac{4v_e}{\sqrt{\pi}v_0} e^{-\frac{v_{esc}^2}{v_0^2}}\right] & v_{min} < v_{esc} - v_e \\ \left[\mathrm{erf}\left(\frac{v_{esc}}{v_0}\right) - \mathrm{erf}\left(\frac{v_{min}(E_R)-v_e}{v_0}\right) - \frac{2}{\sqrt{\pi}v_0}(v_{esc} + v_e - v_{min}) e^{-\frac{v_{esc}^2}{v_0^2}}\right] & v_{esc} - v_e < v_{min} < v_{esc} + v_e \\ 0 & v_{min} > v_{esc} + v_e \end{cases}$$

90% CL no Background



What to expect and What is Next

- We do not have the CL values in case of background, but in the worst case scenario the signal will be distinguished from the background by poissonian statistics. It is possible to evaluate how worse the limits will become with some background

10 background events:	factor 3
100 background events:	factor 8

NEXT

- Calculate all the spectra angular spectra for the different WIMP masses

- Obtain the 3 σ sensitivity curves with background

Formula

$$\frac{dR_Z}{dE_R} = \frac{N_0}{A_M} N_Z \frac{2\rho_0}{m_X^2 r} \sigma_p A^2 F^2 \left(\frac{\mu_A}{\mu_p}\right)^2 \frac{k_0}{2 v_e k_1} \times$$
$$\begin{cases} \left[\operatorname{erf}\left(\frac{v_{min}(E_R)+v_e}{v_0}\right) - \operatorname{erf}\left(\frac{v_{min}(E_R)-v_e}{v_0}\right) - \frac{4v_e}{\sqrt{\pi} v_0} e^{-\frac{v_{esc}^2}{v_0^2}}\right] & v_{min} < v_{esc} - v_e \\ \left[\operatorname{erf}\left(\frac{v_{esc}}{v_0}\right) - \operatorname{erf}\left(\frac{v_{min}(E_R)-v_e}{v_0}\right) - \frac{2}{\sqrt{\pi} v_0}(v_{esc} + v_e - v_{min}) e^{-\frac{v_{esc}^2}{v_0^2}}\right] & v_{esc} - v_e < v_{min} < v_{esc} + v_e \\ 0 & v_{min} > v_{esc} + v_e \end{cases}$$

N_0 *Avogadro number in kg^{-1}*

A_M *Molar mass of molecule of gas*

N_Z *Number of atoms of an element in gas molecule*

ρ_0 *Dark matter mass density next to Solar system*

m_X *Dark matter particle mass*

m_A *Target particle mass*

r *Recoil factor* $r = \frac{4 m_A m_X}{(m_A + m_X)^2}$

A *Mass number of the element*

μ_A *Reduced mass of element*

μ_p *Reduced mass of proton*

v_e *Lab velocity*

v_0 *Galactic thermal dispersion velocity*

v_{min} *Minimum velocity to have recoil energy of E_R*

$$v_{min} = \frac{\sqrt{2 m_A E_R}}{2\mu_A}$$

v_{esc} *Galactic escape velocity*

F *Form factor*

k_0 *Normalization of regular velocity distribution*

k_0 *Normalization of cut velocity distribution*