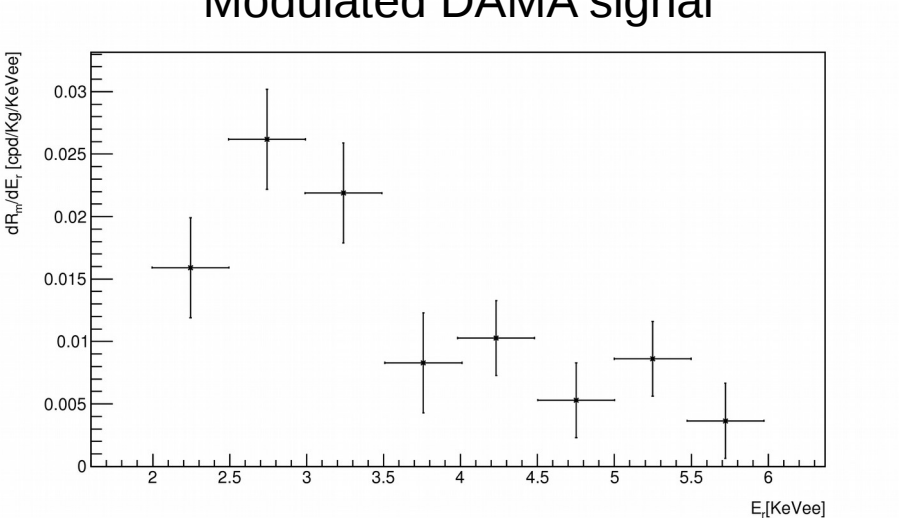
# Study of the SABRE experiment sensitivity

Irene Bolognino, Davide D’Angelo, Nicola Rossi, **Valerio Toso**

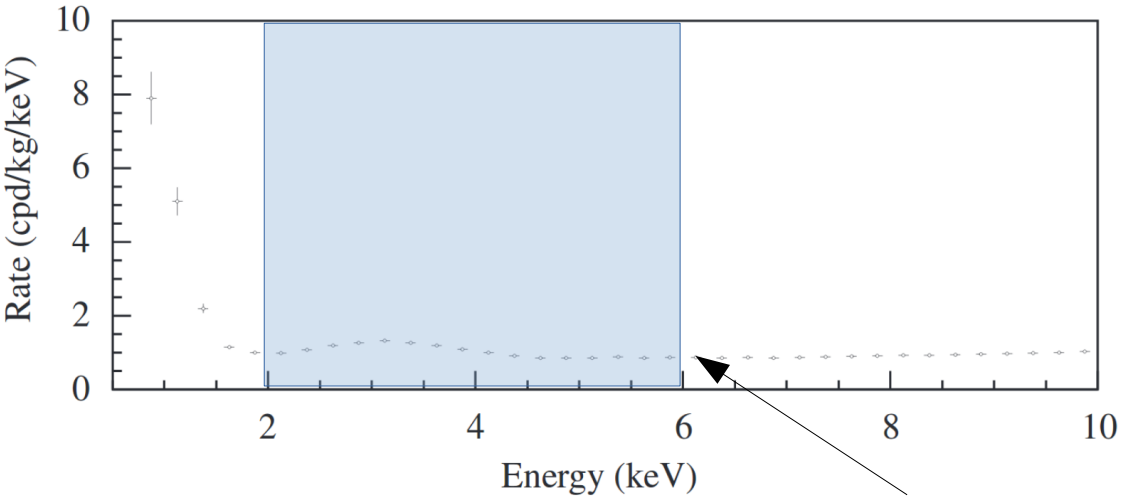
The spin-independent WIMP-nucleus interaction rate is a function of the WIMP mass and the WIMP-nucleon interaction cross section.

To get these values we fit the DAMA modulation signal in the 2-6 keVee energy region.

Modulated DAMA signal




Unmodulated DAMA signal




4 cpd/kg

Minimizing the fit $\chi^2$ we find which are the best values of WIMP mass and cross section that reproduce the experimental data.

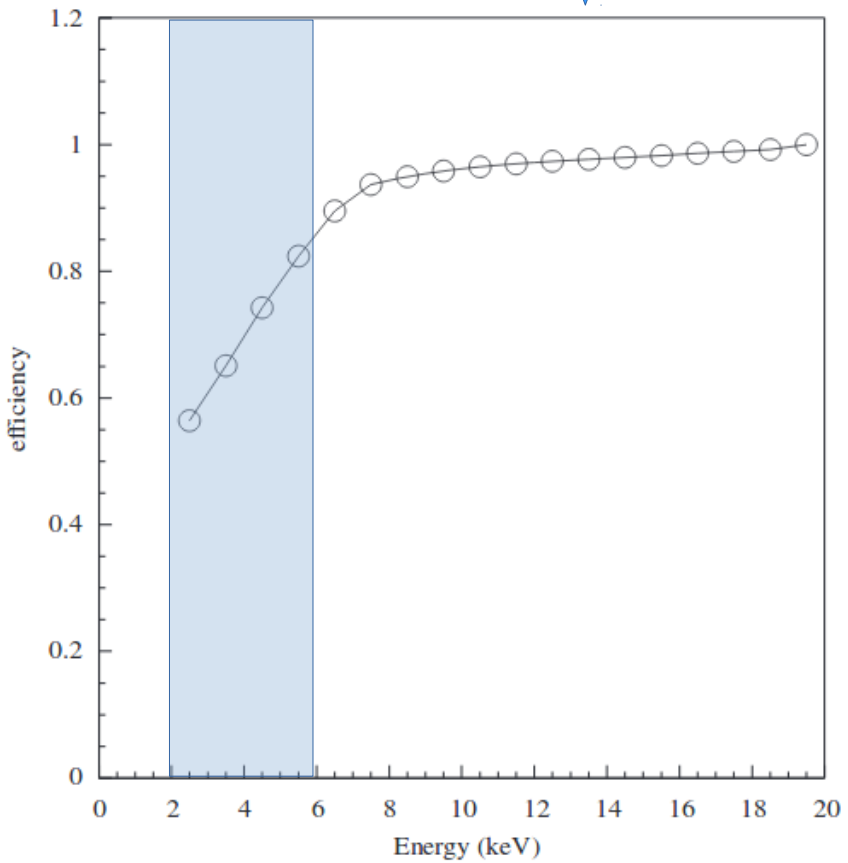
$$\chi^2 = \sum_{1}^{NDAT} \left(\frac{R^i_{exp} - R^i_{theo}}{\sigma_{R^i_{exp}}}\right)^2 + \left(\frac{R^{TOT}_{exp} - R^{TOT}_{theo}}{\sigma_{R^{TOT}_{exp}}}\right)^2 \Theta(R^{TOT}_{exp} - R^{TOT}_{theo})$$

Penalty on the total rate

Step function

Energy resolution: $\frac{\sigma(E)}{E} = 0.0091 + \frac{0.488}{\sqrt{E}}$

R. Bernabei et al., Nuclear Instruments and Methods in Physics Research A, 592 297-315, 2008




Threshold efficiency

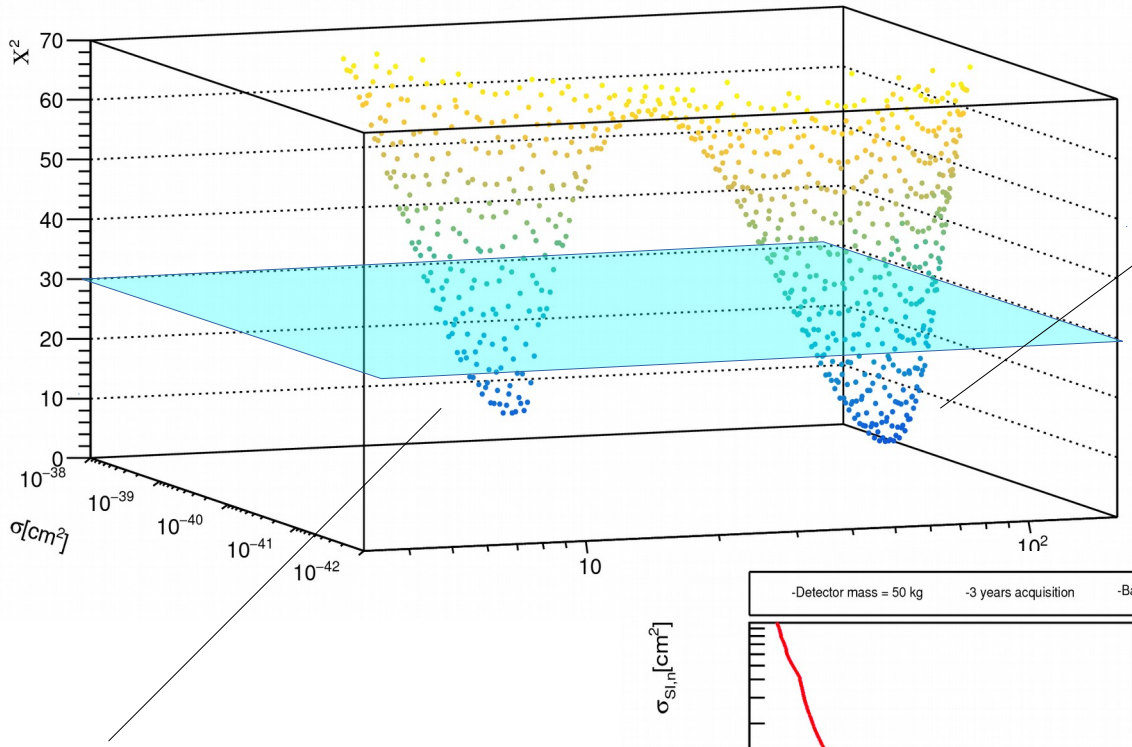
Quenching factor for iodine 0.09 and for sodium:

| Recoil energy [$keV_{ee}$] | Quenching factor |
|---|---|
| 0.76 ± 0.4 | 0.133 ± 0.018 |
| 1.13 ± 0.5 | 0.129 ± 0.014 |
| 1.46 ± 0.5 | 0.162 ± 0.012 |
| 2.21 ± 0.9 | 0.159 ± 0.019 |
| 2.36 ± 0.8 | 0.160 ± 0.010 |
| 3.21 ± 1 | 0.168 ± 0.009 |
| 4.10 ± 1.5 | 0.171 ± 0.010 |
| 5.36 ± 1.9 | 0.188 ± 0.008 |
| 6.19 ± 2.1 | 0.191 ± 0.011 |
| 8.53 ± 2.7 | 0.204 ± 0.008 |
| 10.59 ± 4.5 | 0.207 ± 0.010 |

Jingke Xu et al., arXiv, (1503.07212v1), 2015

# $\chi^2$ values for couples $(m_{DM}, \sigma_{SI,n})$

$(1GeV \leq m_{DM} \leq 1000GeV)$, $(10^{-42} \leq \sigma_{SI,n} \leq 10^{-38})$




Absolute minimum $\chi^2/\mathrm{NDF} = 1.2$

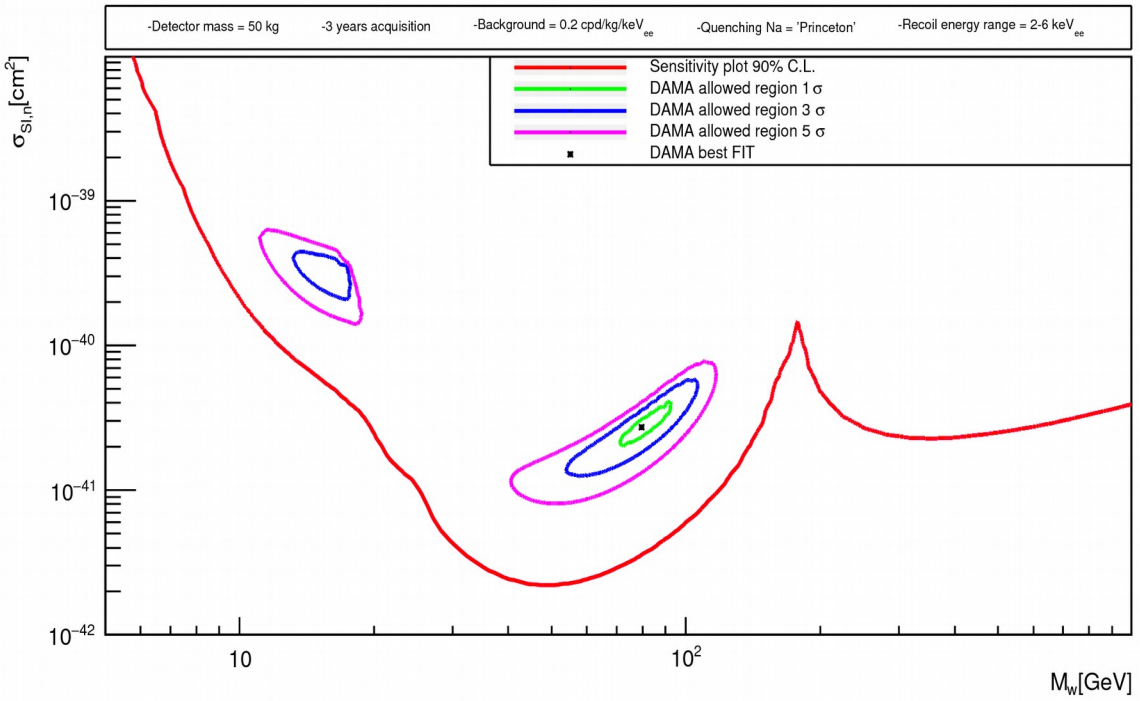
$\sigma_{SI,n} = 2.8^{+0.8}_{-0.5} \cdot 10^{-41} cm^2$

$m_{DM} = 83^{+4}_{-8} GeV$

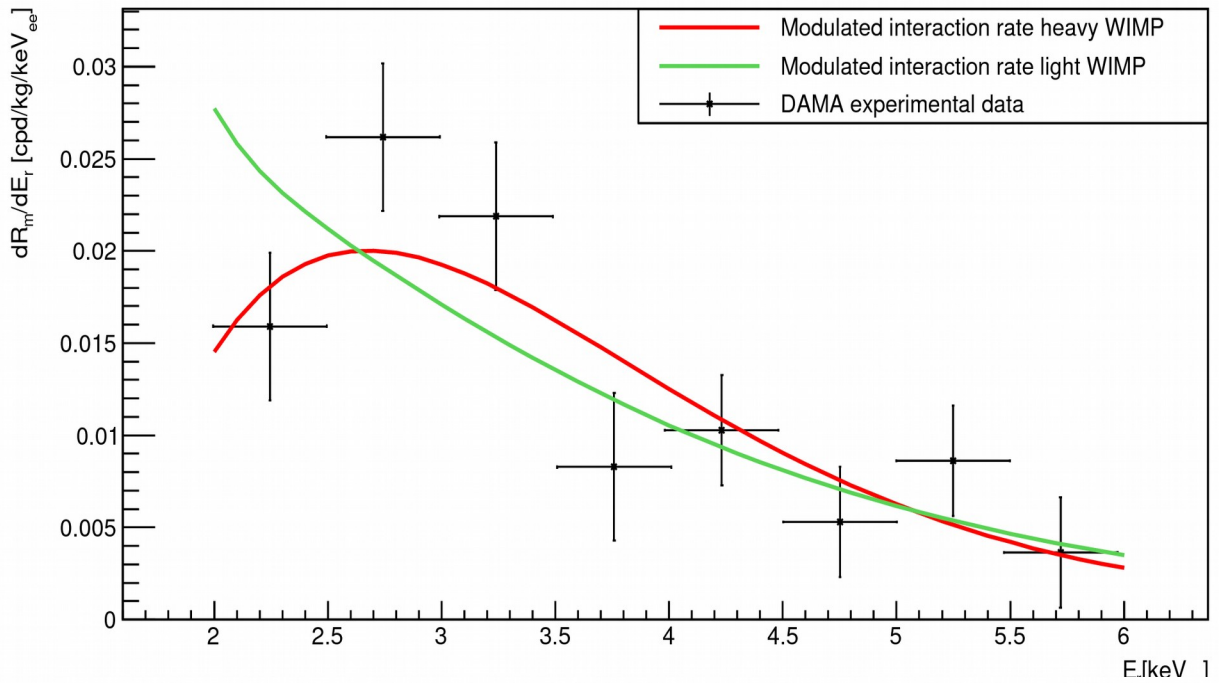
Relative minimum $\chi^2/\mathrm{NDF} = 2.5$

$\sigma_{SI,n} = 1.8 \pm 0.3 \cdot 10^{-40} cm^2$

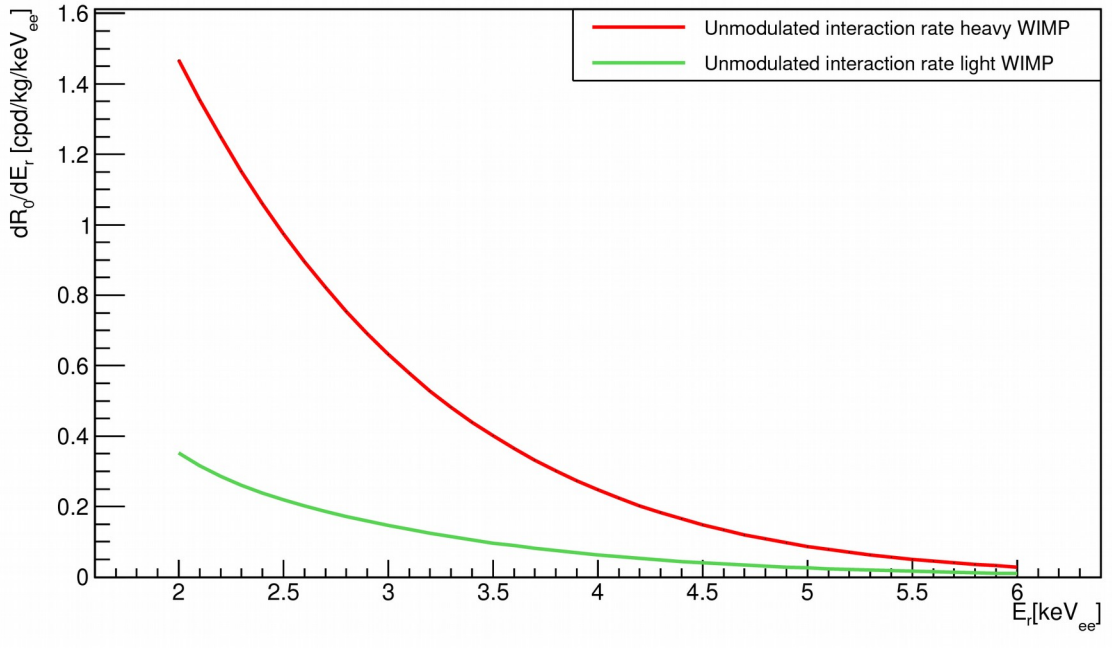
$m_{DM} = 15 \pm 2 GeV$



Heavy WIMP ~ 80 GeV
Light WIMp ~ 15 GeV




Modulated interaction rate over the DAMA measured data




Non modulated interaction rate

# Sensitivity Plot

-50 kg NaI detector

-0.2 cpd/kg/keVee background rate

-3 years exposure time

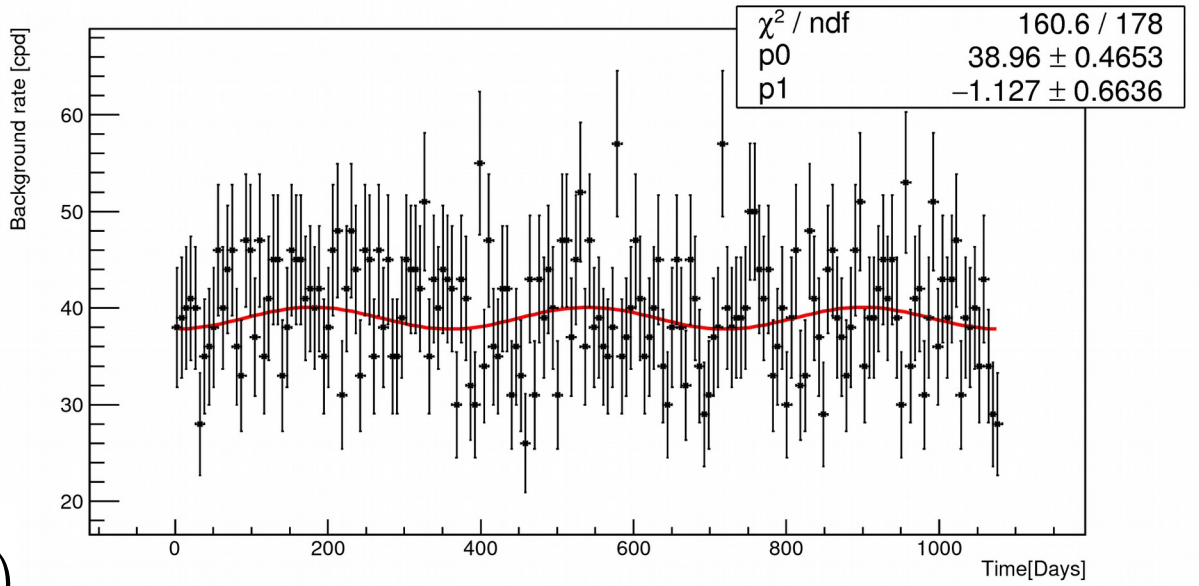
-(2-6) keVee recoil energy range

-Quenching factor for iodine = 0.09

-Quenching factor for sodium measured by Jingke Xu et al., arXiv, (1503.07212v1), 2015

**Only background signal as an assumption**

Background signal with a Poisson distribution centered in 0.2 cpd/kg/keVee * 4keVee * 50kg

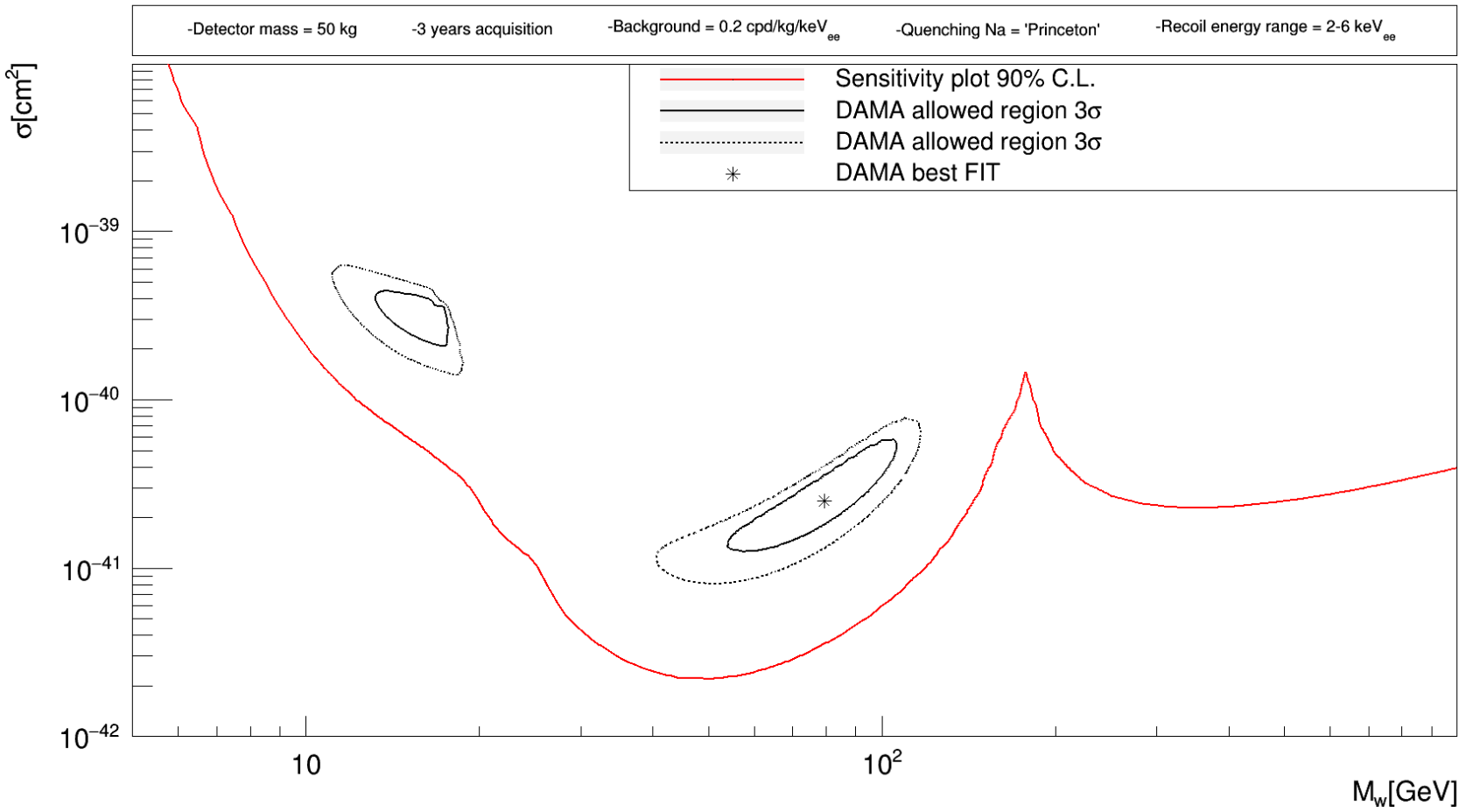



FIT with a function:

$$y = p_0 + p_1 cos(\frac{2\pi}{365}t)$$

- 1000 background-only generated signals and FIT
- Standard deviation $\sigma_{FIT}$ of the amplitude of every sinusoidal function from each FIT

1.64 *$\sigma_{FIT}$ correponds to 90% C.L. limit in case of no oscillation, limited basically by the injected background fluctuation



# Quenching factor

How is the 90% C.L. sensitivity plot affected by a change in the sodium quenching factor?

DAMA sodium quenching factor = 0.3
(Energy independent)

Quenching factor measured by Jingke Xu et al. (Princeton university), arXiv, (1503.07212v1), 2015

| Recoil energy [$keV_{ee}$] | Quenching factor |
|---|---|
| 0.76 ± 0.4 | 0.133 ± 0.018 |
| 1.13 ± 0.5 | 0.129 ± 0.014 |
| 1.46 ± 0.5 | 0.162 ± 0.012 |
| 2.21 ± 0.9 | 0.159 ± 0.019 |
| 2.36 ± 0.8 | 0.160 ± 0.010 |
| 3.21 ± 1 | 0.168 ± 0.009 |
| 4.10 ± 1.5 | 0.171 ± 0.010 |
| 5.36 ± 1.9 | 0.188 ± 0.008 |
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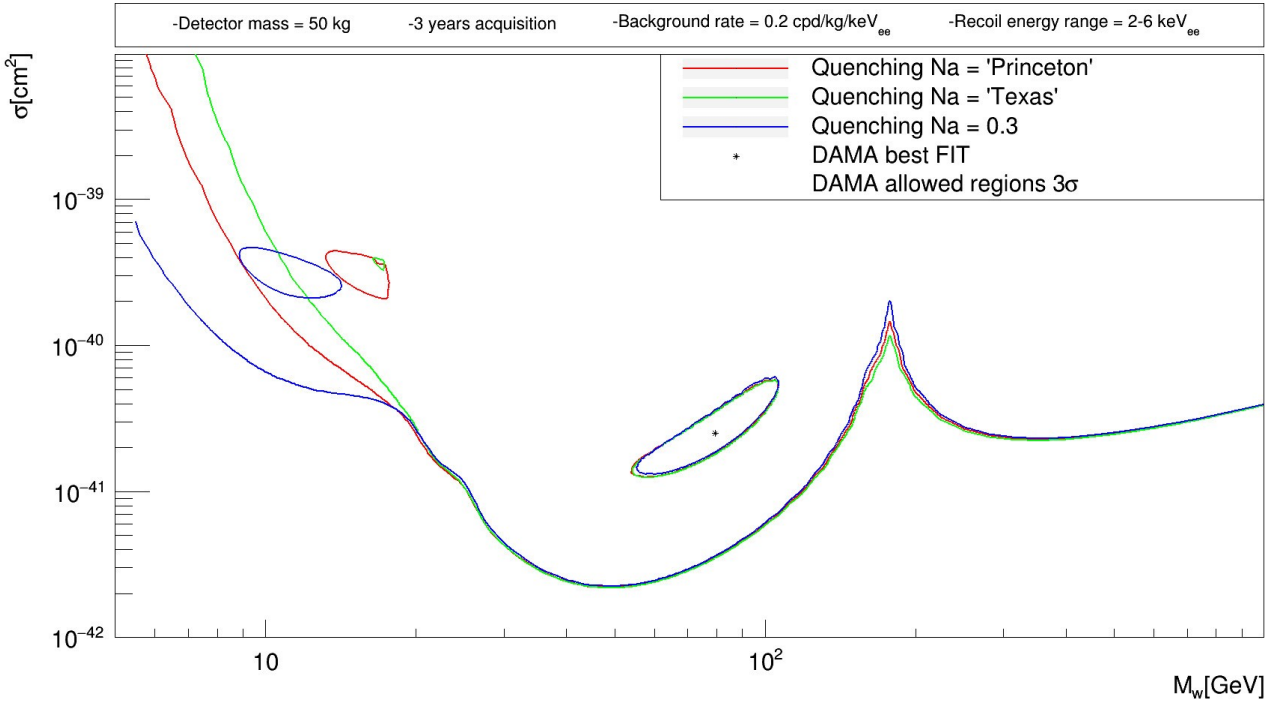
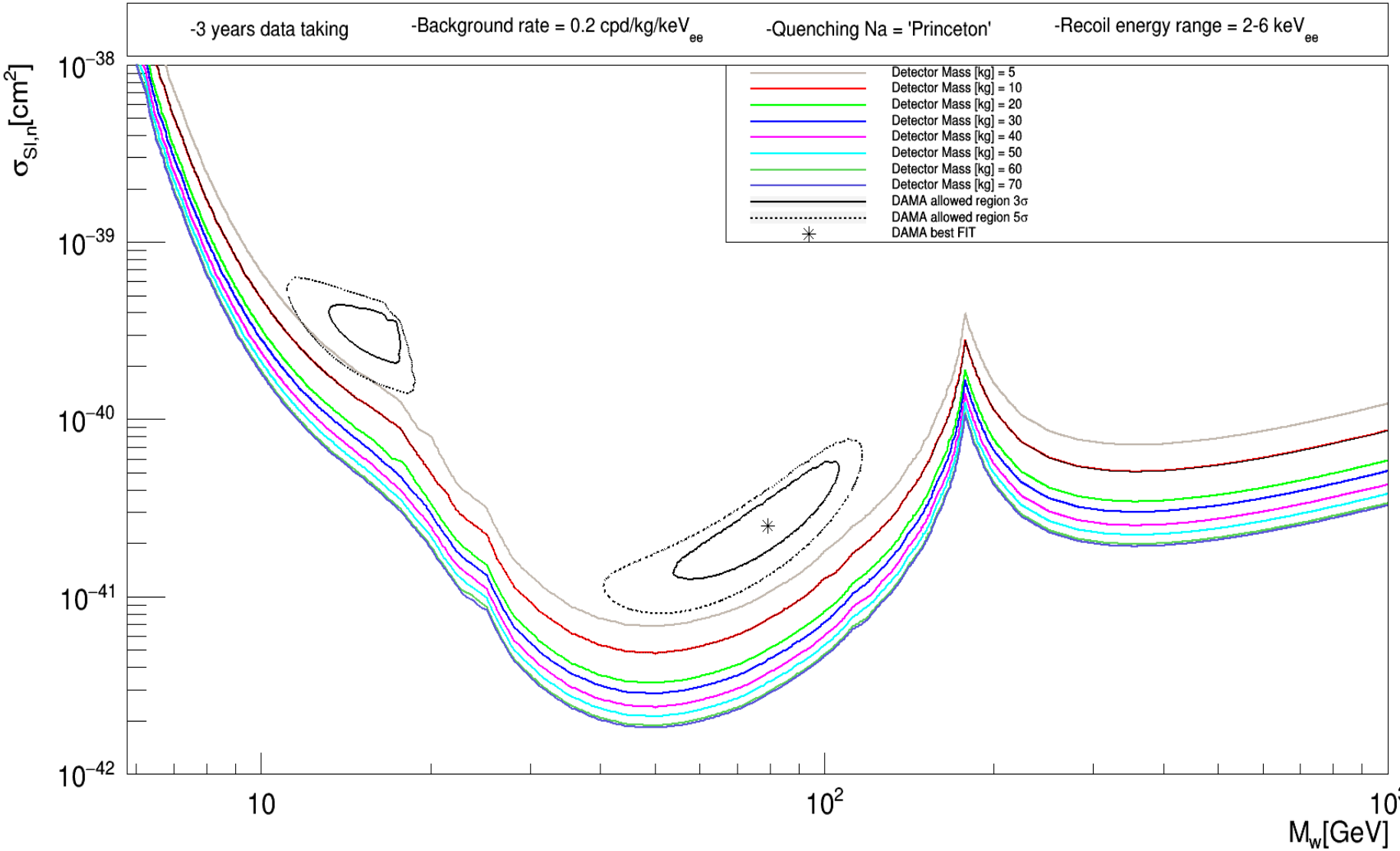



| Recoil energy [$keV_{ee}$] | Quenching factor |
|---|---|
| 0.470 | 0.056 |
| 0.584 | 0.080 |
| 0.646 | 0.068 |
| 0.928 | 0.080 |
| 1.858 | 0.105 |
| 2.600 | 0.125 |
| 4.275 | 0.1425 |
| 4.788 | 0.1525 |
| 4.816 | 0.140 |
| 7.200 | 0.180 |
| 8.586 | 0.180 |

Quenching factor measured by by Tyana Stiegler et al. (Texas A & M University), arXiv, (1706.07494v1), 2017

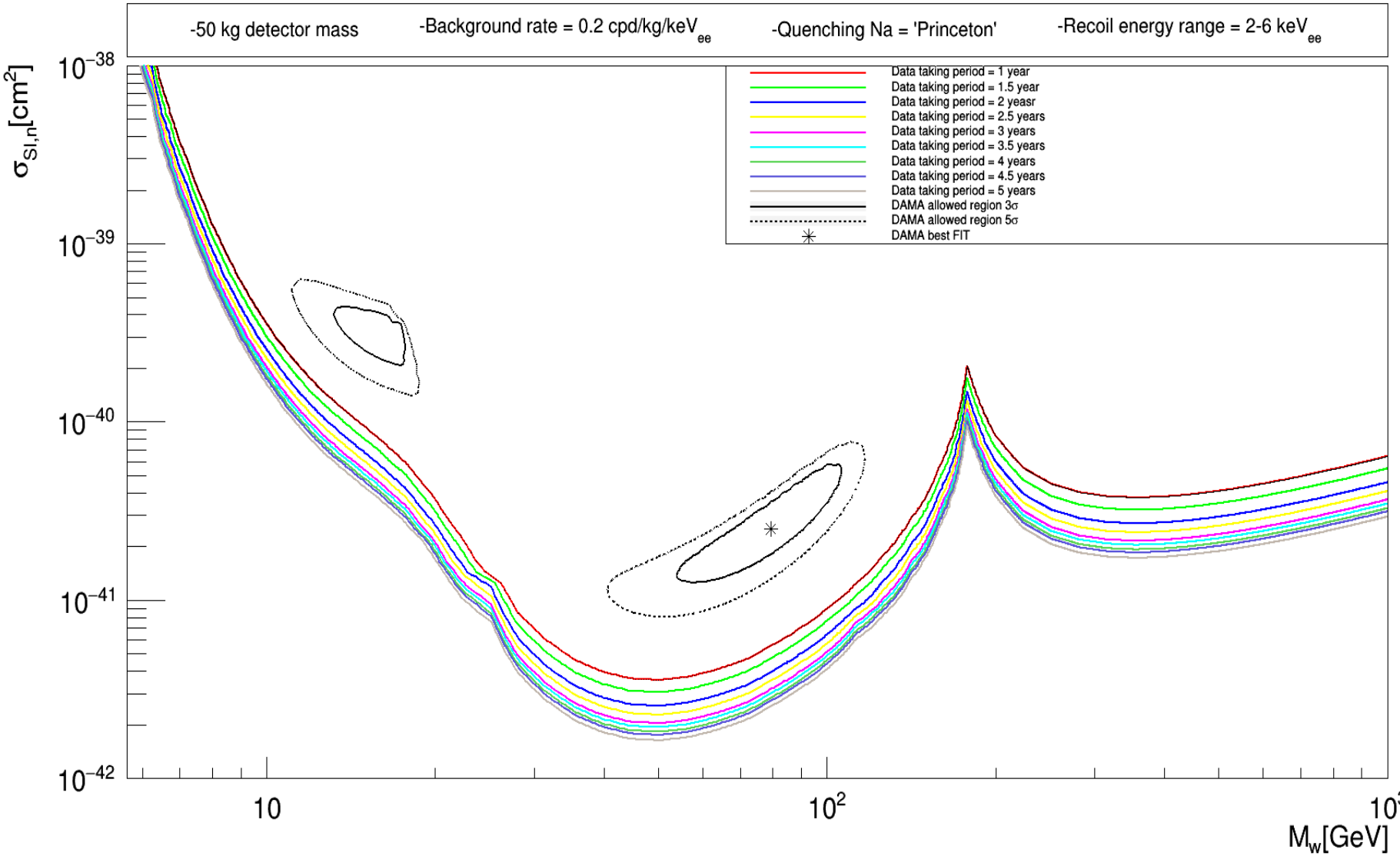
# Detector mass

How is the 90% C.L. sensitivity plot affected by a change in the detector mass?



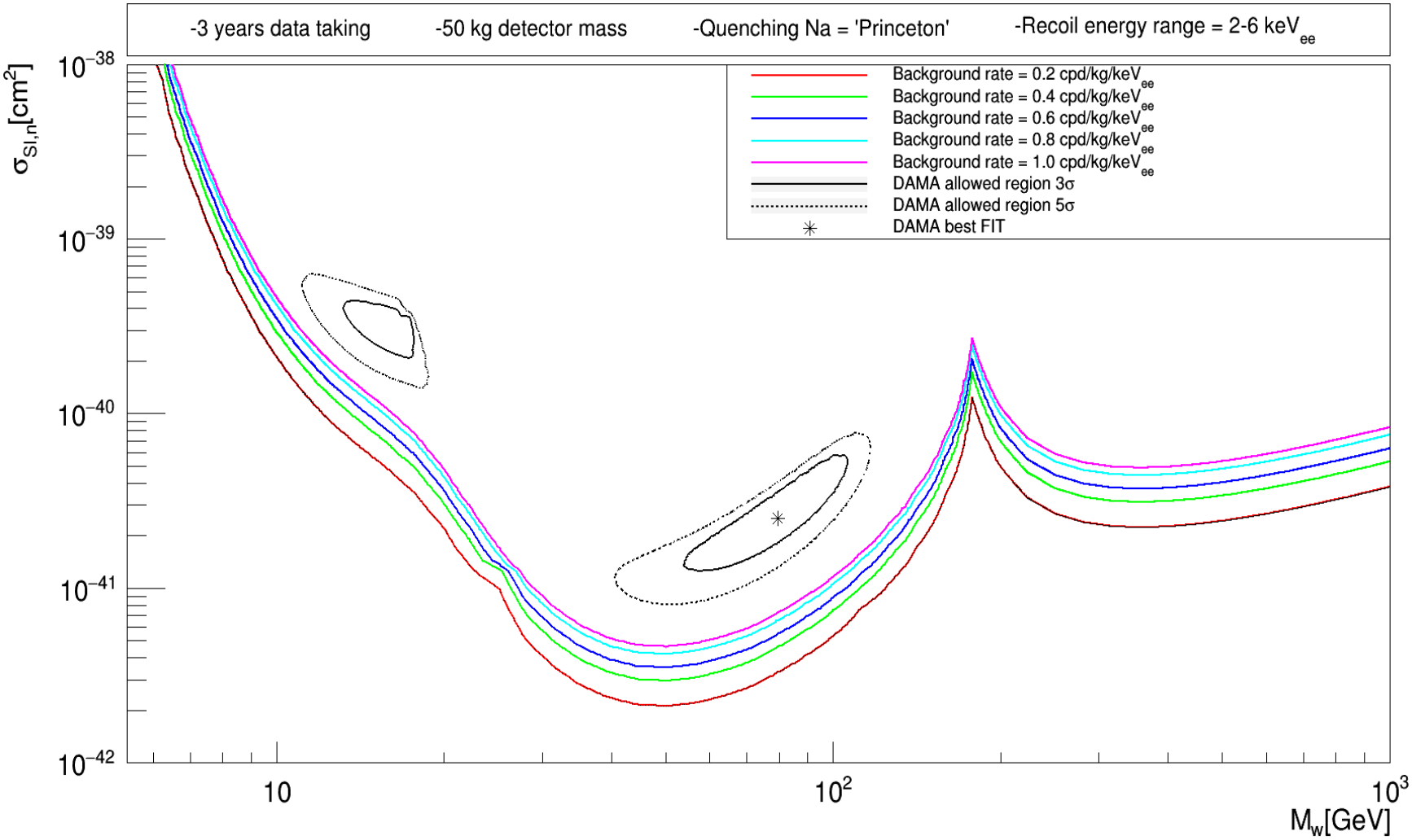
# Data taking time

How is the 90% C.L. sensitivity plot affected by the acquisition time?

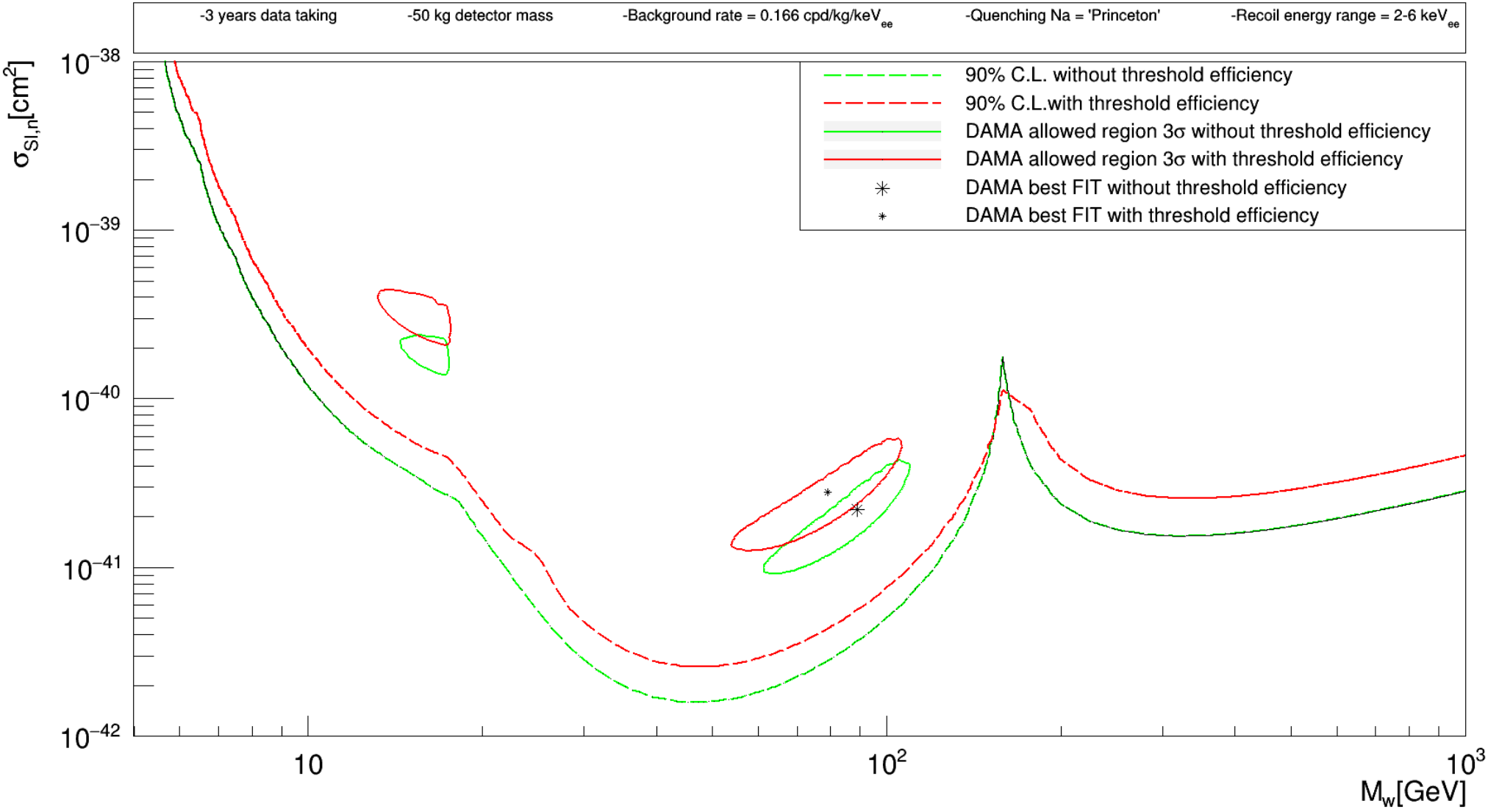


# Background rate

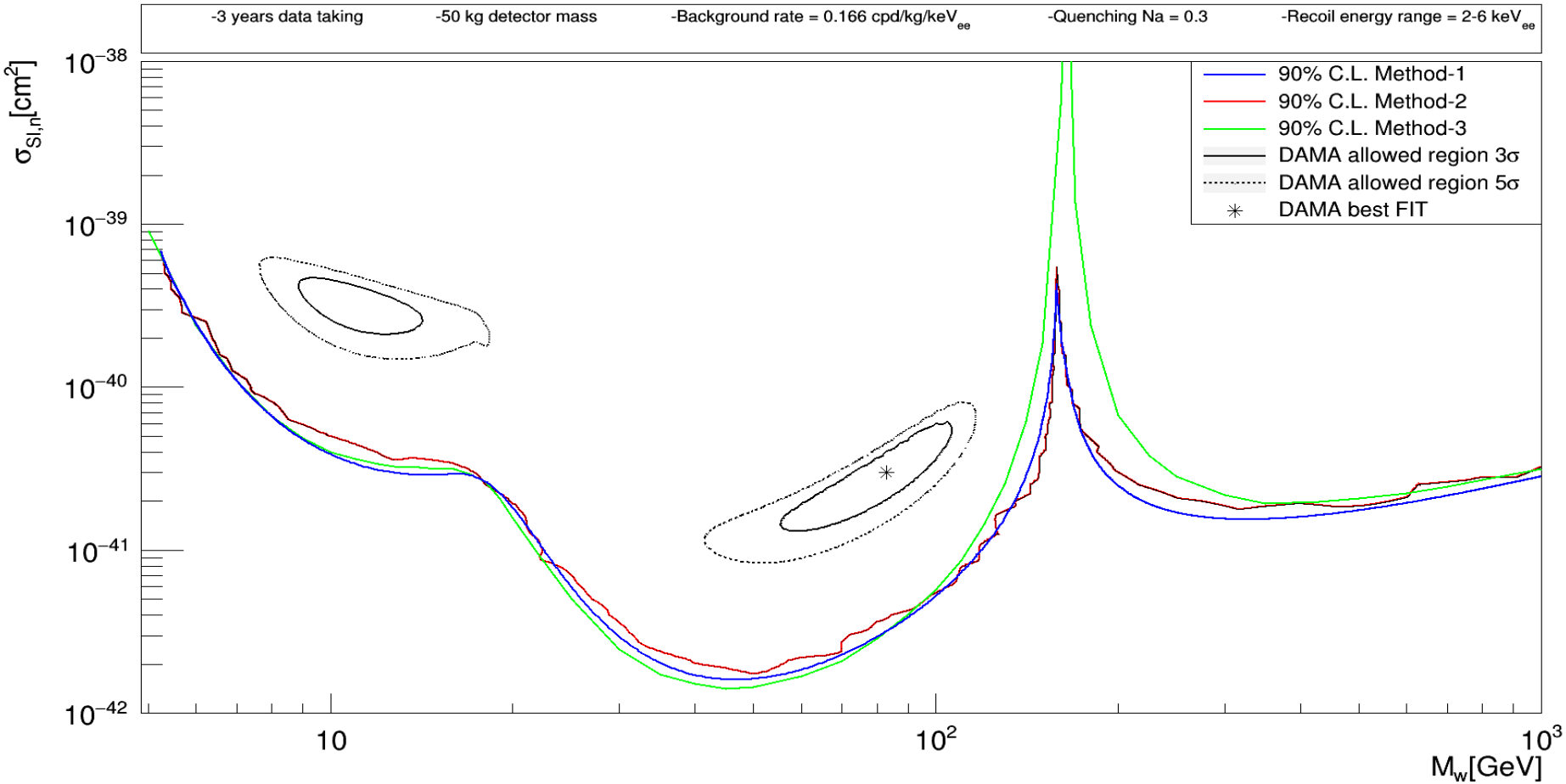
How is the 90% C.L. sensitivity plot affected by the background rate?



# Threshold efficiency



# Comparison with a different method:

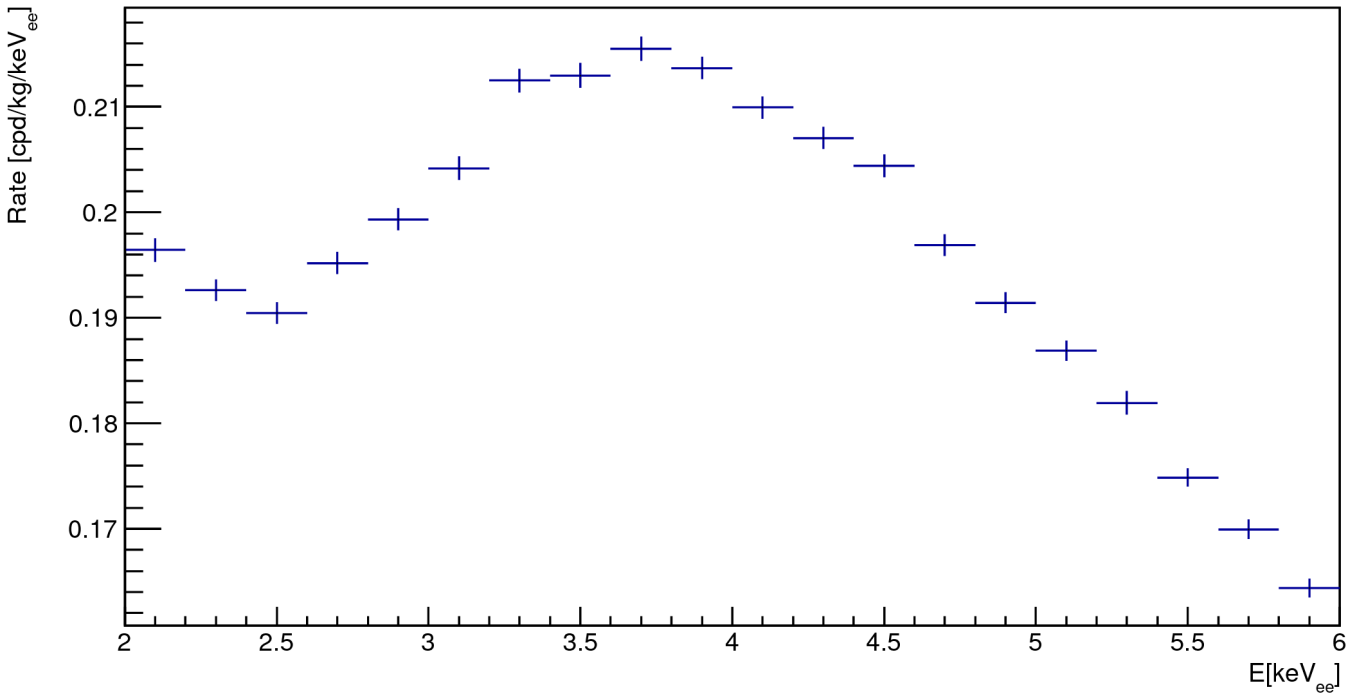



- Method 1 represent an exclusion limit
- Methods 2,3 represent a limit of discovery

Method-3: SABRE NOTE 003-2017

# Next steps:

- Sensitivity plot with an energy dependent background




Simulations expected background rate after 6 months

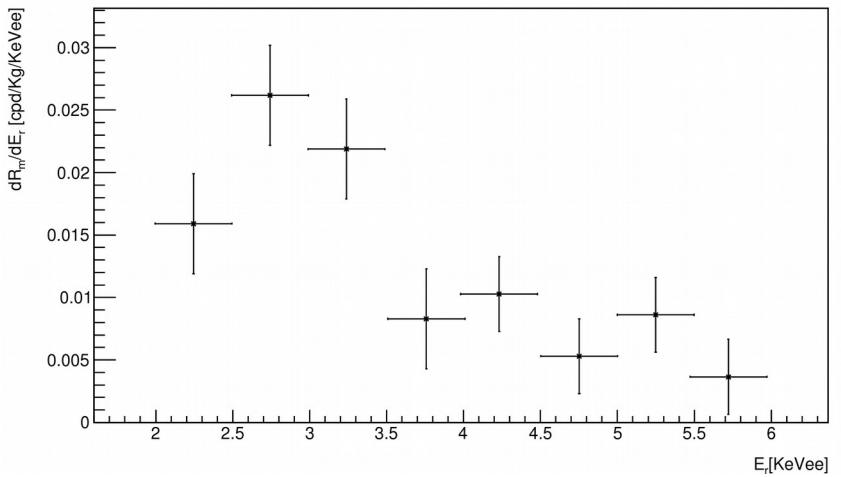
- Maximum likelihood estimation

SABRE-NOTE 004–2017
(in preparation)

# Backup slides

- 5 kg NaI
- 0.2 cpd/kg/keVee background rate
-3 years exposure time

Modulated DAMA signal

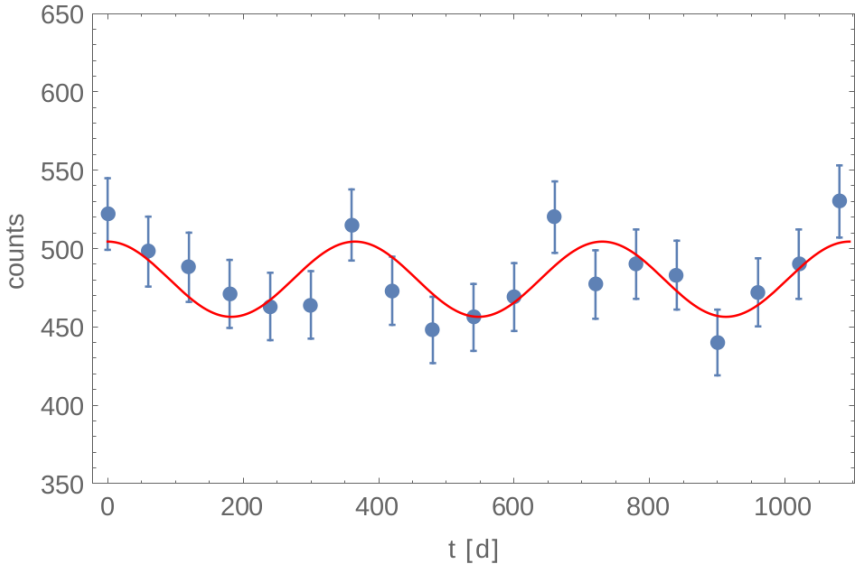



Total modulated rate in
2-6 keVee = 0.05 cpd/kg

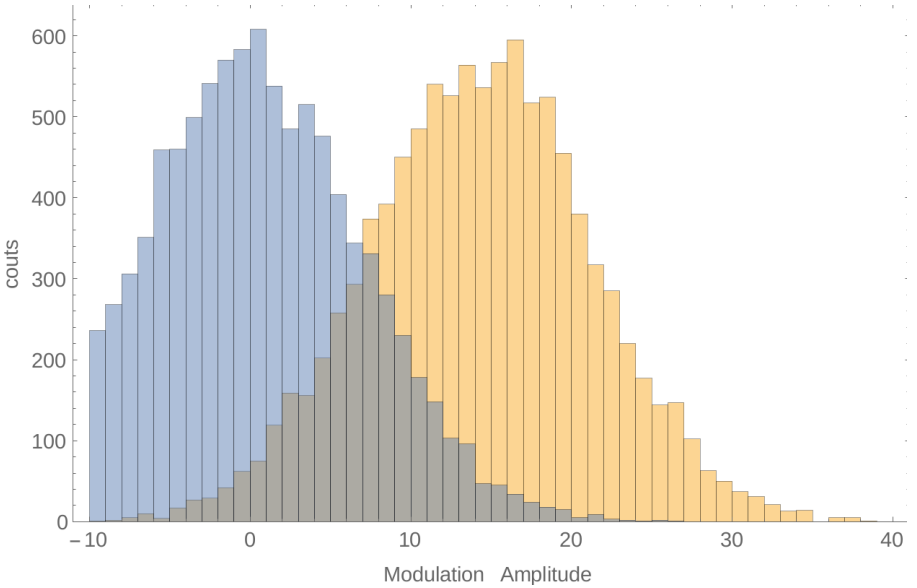
Background rate in 60 days:

0.2 cpd/kg/keVee * 4 keVee * 5kg * 60 days = 240 counts/60d
+ unmodulated rate =15 / 0.07 counts/60d

0.05 cpd/kg * 5kg * 60 days = 15 counts/60d




Poisson distribution of the rates and fit

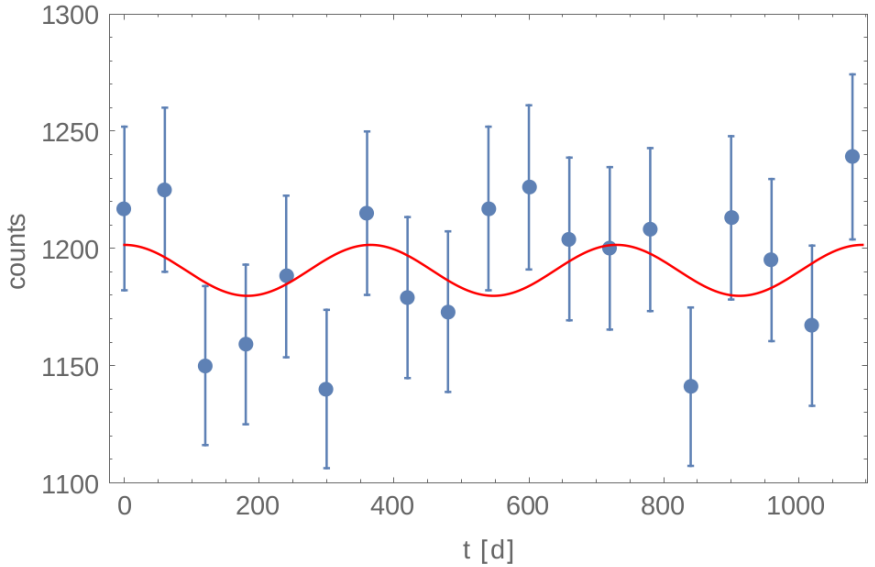


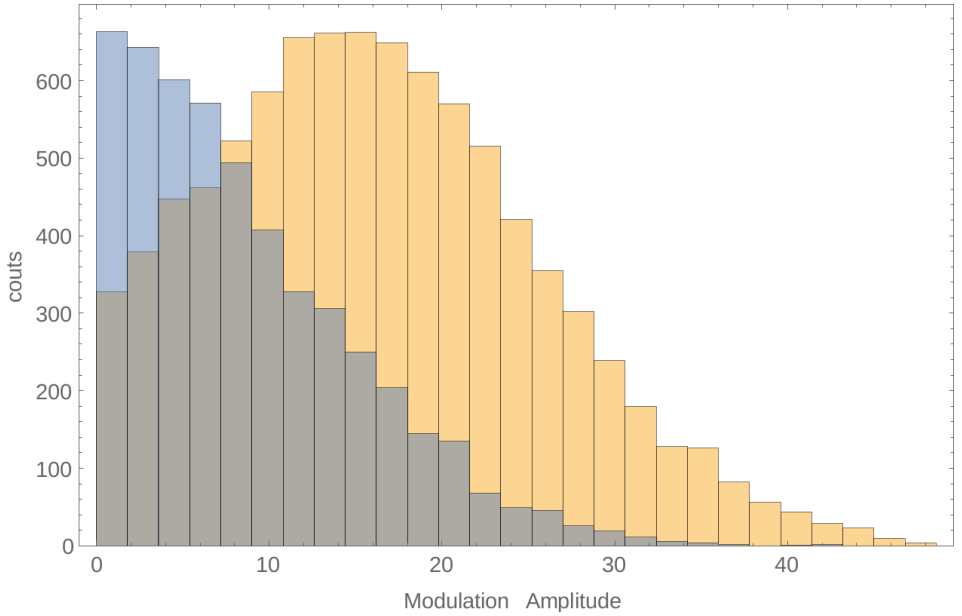
# With 1 cpd/kg/keVee?

- 5 kg NaI
- 1 cpd/kg/keVee background rate

0.05 cpd/kg * 5kg * 60 days = 15 counts

1 cpd/kg/keVee * 4 keVee * 5kg * 60 days = 1200 counts




DAMA background 1cpd/kg/keVee