Very preliminary study in view of DM limit estimation with LIME

Assumptions

- **Method**: Bayesian approach (to obtain posterior probability on expected signal and background events)
- **Dataset**: Run4
- **Events <-> cross-section SI relation:**

$$N_{DMevt,i} = tV\frac{P}{P_{atm}}\frac{T_0}{T}\rho_i\frac{N_0}{A_{mol,i}}\frac{2\rho_0\sigma_{n,SI}}{m_\chi^2 r_i}\frac{\mu_{A,i}^2}{\mu_n^2}A_i^2 I_i^{E\gamma}(m_\chi, E_{thr,i}),$$

- **Energy threshold: 1kV$_{ee}$**

Dataset

Run4 [43887 - 55097] -> period [15/01/2024 - 08/04/2024]

Background: 20% of the total runs, randomly extracted

Data: 80% of the total runs

Cut (both on data and background):

- Sc_rms > 6
- Sc_integral > 500
- Sc_xmin, sc_ymin > 300
- Sc_xmax, sc_ymax < 2000
- 0.005 < rho < 0.15

Exposure time

Exposure time = T - n*t_{wf}

T = total time of the run

n = number of events in the image (without cuts)

t_{wf} = PMT time = 0.01 s

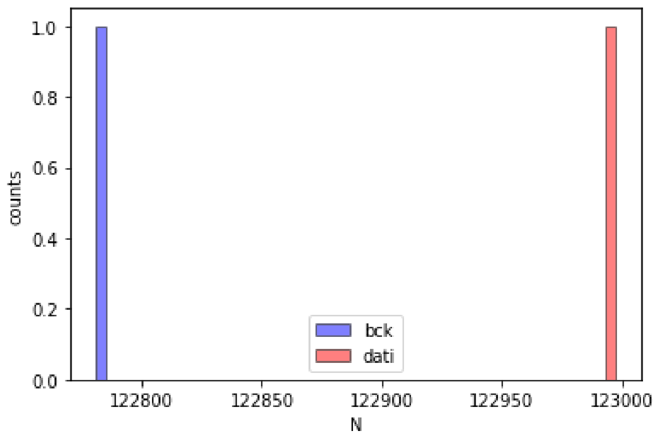
Evaluation of the background and data number of events

1) After applying all the cuts, the number of events is evaluated
2) Data: the total number of events and exposure time is evaluated
3) Background: the total number of events and exposure time is evaluated, the number of events are rescaled to the data exposure time

Example

1) Evaluation of the number of data and background events

Exposure time = 2367964 s




```
bck:  122781.1202732629 +/- 0.0 +/- 350.40137025026445
data:  122996.97508868681 +/- 0.0 +/- 350.7092457986912
```

Application of the Bayesian approach

To infer the posterior probability on expected signal (μ_s) and background (μ_b) events.

C.I. 90% on μ_s posterior.

Likelihood:

$$\mathcal{L}(\vec{x}|\mu_s, \mu_b, H_1) = \frac{(\mu_b + \mu_s)^{N_{evt}}}{N_{evt}!} e^{-(\mu_b+\mu_s)}$$

Prior:

- Background: poissonian distribution
- Signal: flat distribution

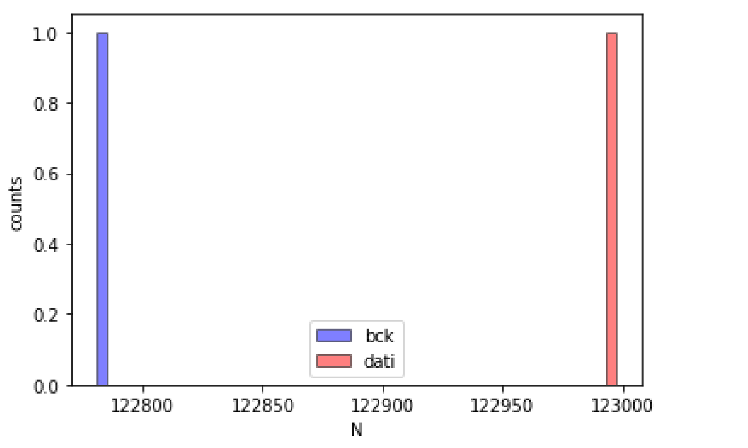
Posterior:

Evaluated thanks to the BAT software

Example

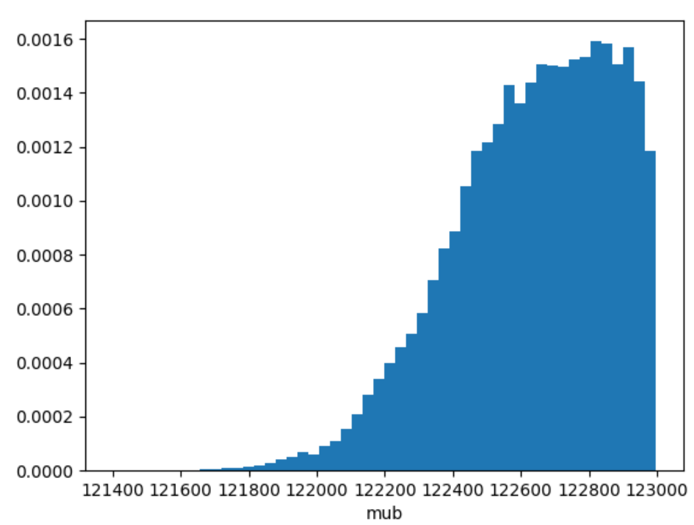
1) Evaluation of the number of data and background events

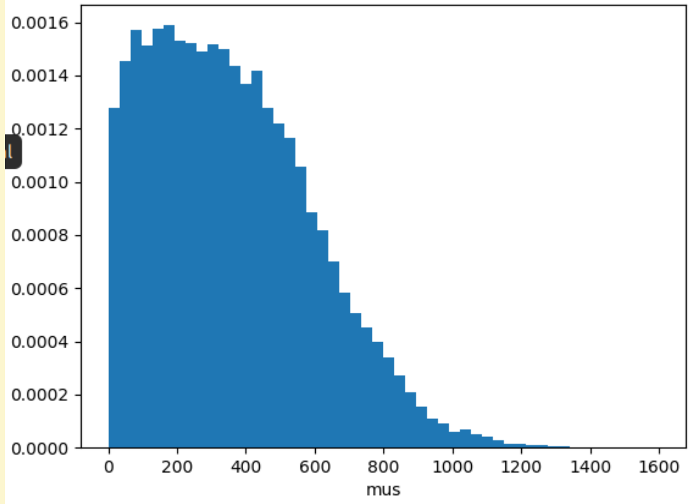
Exposure time = 2367964s




```
bck:  122781.1202732629 +/- 0.0 +/- 350.40137025026445
data:  122996.97508868681 +/- 0.0 +/- 350.7092457986912
```

2) Posterior probability on expected signal (μ_s) and background (μ_b) events





μ_s 90% C.I = 686

Evaluation of the cross section

We need to invert this formula:

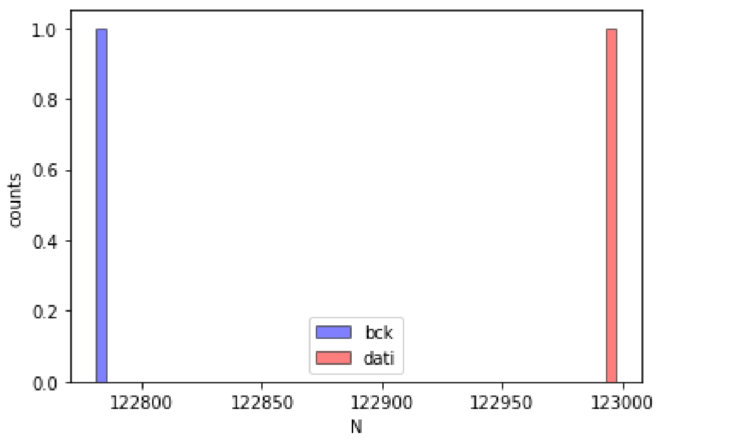
$$N_{DMevt,i} = tV\frac{P}{P_{atm}}\frac{T_0}{T}\rho_i\frac{N_0}{A_{mol,i}}\frac{2\rho_0\sigma_{n,SI}}{m_\chi^2 r_i}\frac{\mu_{A,i}^2}{\mu_n^2}A_i^2 I_i^{E\gamma}(m_\chi, E_{thr,i}),$$

- Gas mixture = He:CF_4
- I need:
  - t (= exposure time [s])
  - V (= volume [m^3])
  - P (= pressure [bar])

Example

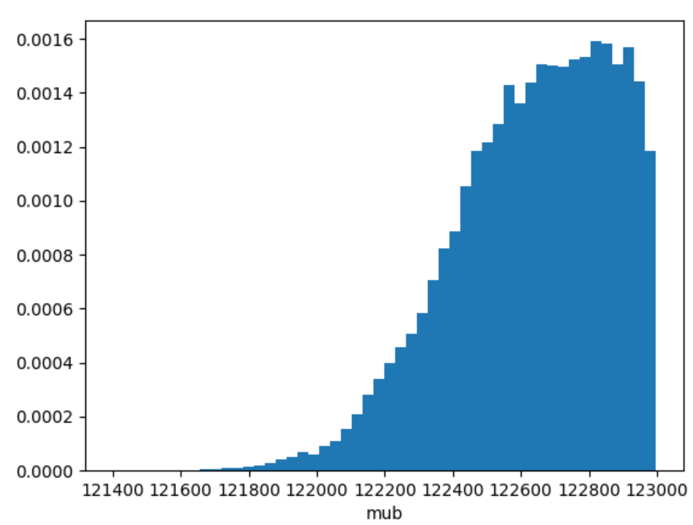
1) Evaluation of the number of data and background events

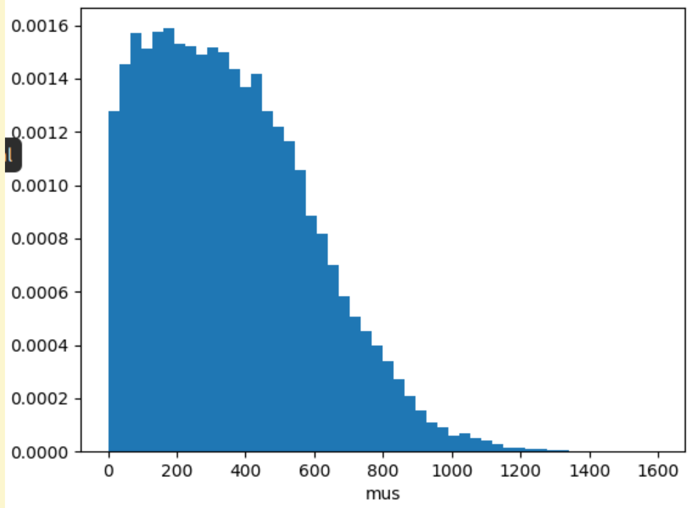
Exposure time = 2367964




```
bck:   122781.1202732629 +/- 0.0 +/- 350.40137025026445
data:   122996.97508868681 +/- 0.0 +/- 350.7092457986912
```

2) Posterior probability on expected signal (μ_s) and background (μ_b) events





μ_s 90% C.I = 686

2) Evaluation of the cross section SI

t = 2367966 s

V = xyz = 0.03 m^3

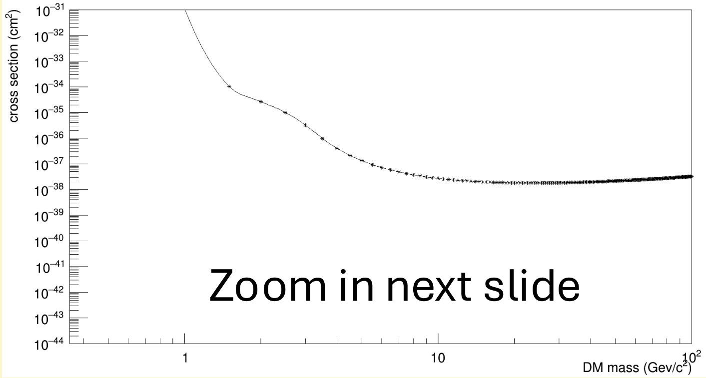
x = 1700 pixel * 152 μm = 0.25 m

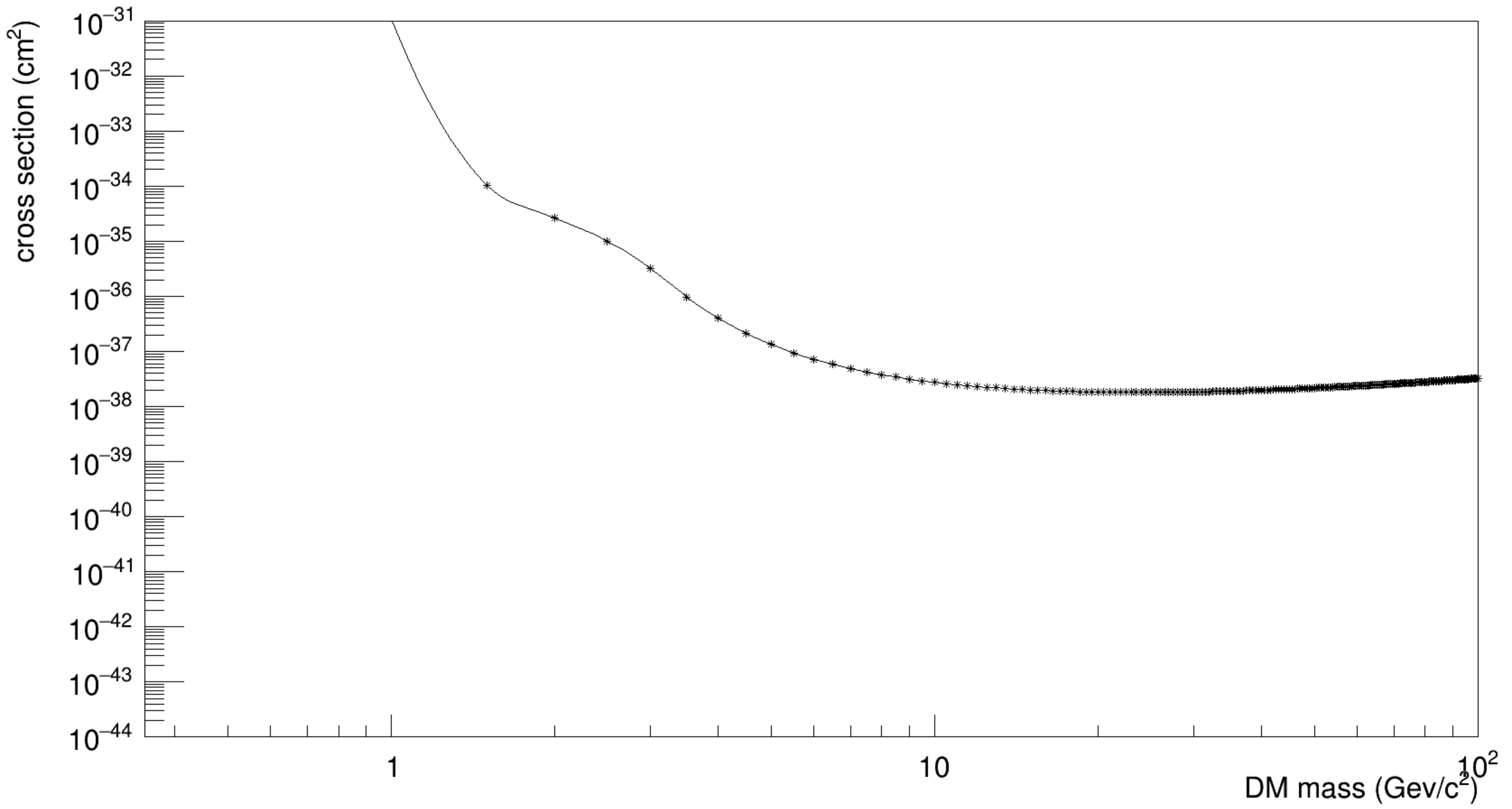
y = 1700 pixel * 152 μm = 0.25 m

z = 0.48 m

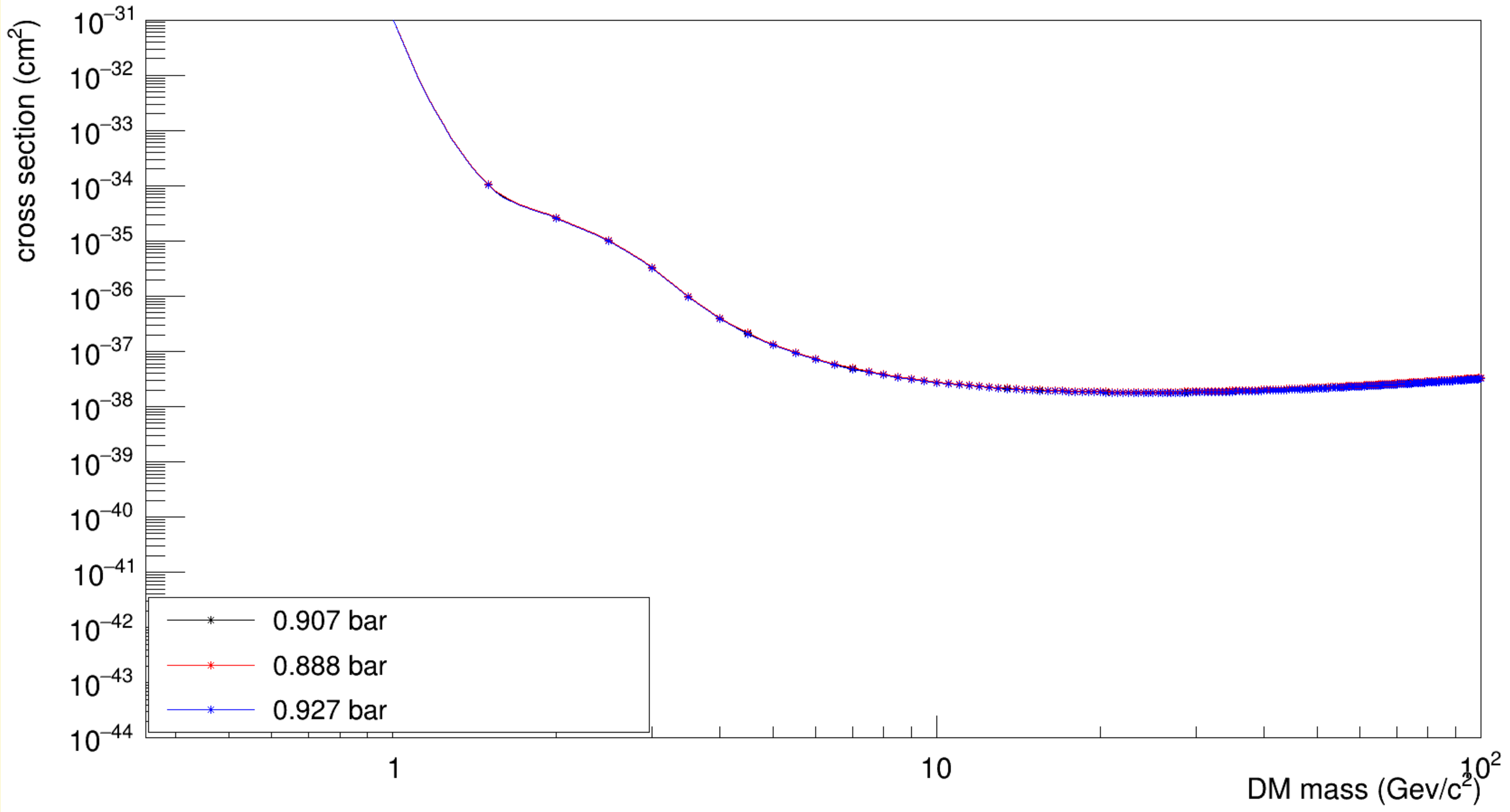
P = 0.907 bar

Given by the average pressure

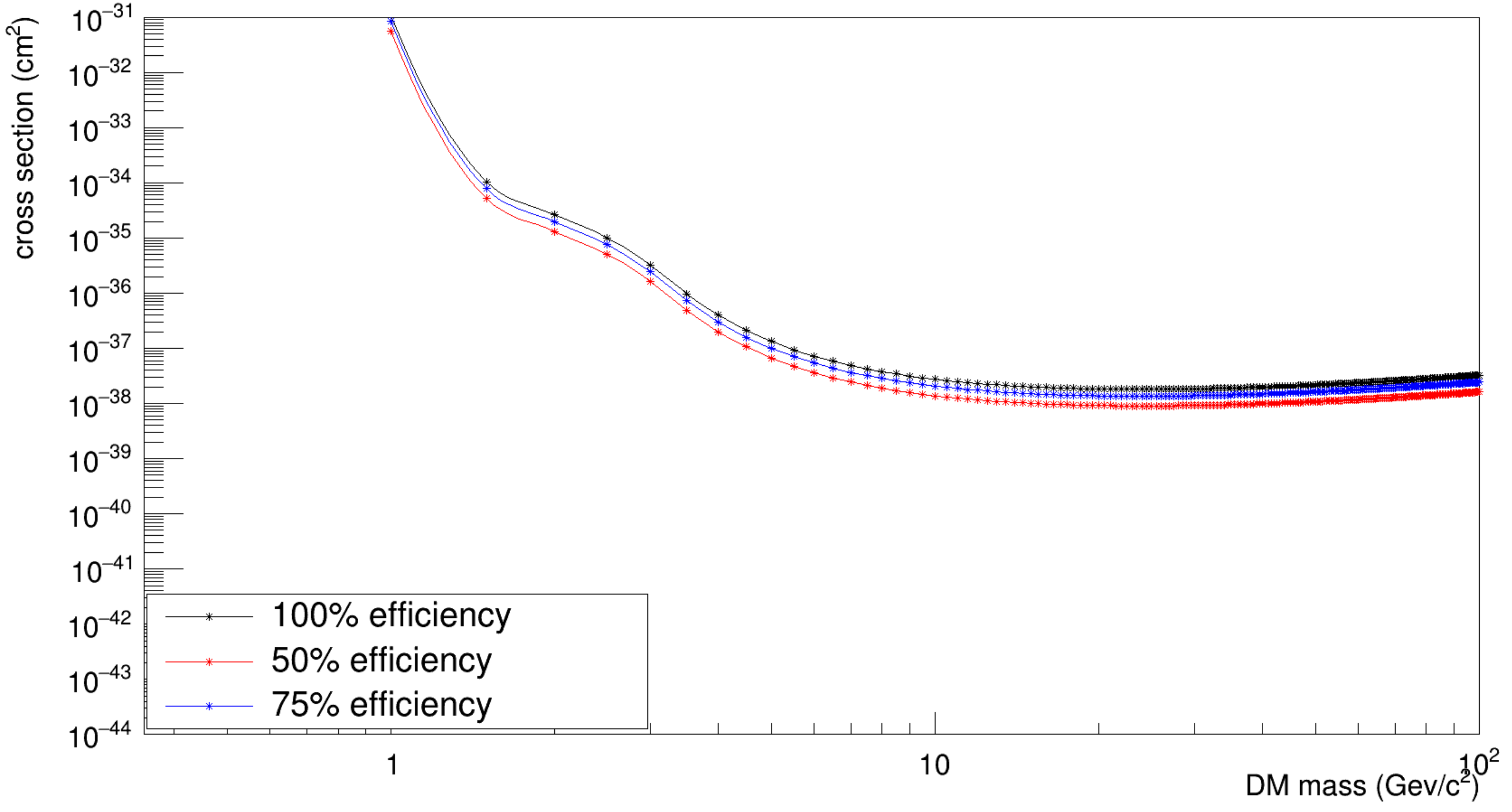



cross section (cm²)
10⁻³¹
10⁻³²
10⁻³³
10⁻³⁴
10⁻³⁵
10⁻³⁶
10⁻³⁷
10⁻³⁸
10⁻³⁹
10⁻⁴⁰
10⁻⁴¹
10⁻⁴²
10⁻⁴³
10⁻⁴⁴
1
10
10²
DM mass (Gev/c²)

Changing the pressure?



Changing the efficiency? P = 0.907 bar



Changing the threshold? P = 0.907 bar, efficiency = 100%