LIME DM rough limit estimation

G. Dho

28/03/2024

These are not the true limits

- **Important disclaimer**: these are not meant to be showed outside the collaboration

They are meant to give ballpark indications of where the LIME limits should be and how much we can gain with increasing the exposuretime of Run4

Assumptions

- **Method:** Bayesian approach with likelihood fit to obtain posterior probability on expected signal (μ_s) and background events of simulated experiments. C.I. 90% on μ_s posterior.
- **Signal:** Standard Halo Model with same parameters as in the CYGNO paper
- **Material:** He:CF_4 60/40
- **Signal theoretical influence:** Quenching factor of all elements,
  Probability of each element of being hit and detected,
  Bin migration effect (resolution).
- **Variable of interest:** Full 2D angular distribution (Galactic coordinates.. Means 3D reconstruction)
- **Experimental characteristics:** 1 or 2 keV_{ee} energy threshold
  30x30 deg^2 angular resolution down to energy threshold
  Full HT down to energy threshold
- **Background:** Perfectly flat in Galactic coordinates
- **Data sample:** 100 repetitions of fake experiments made by random extractions of only background events (poissonian extraction from expected background μ_b)

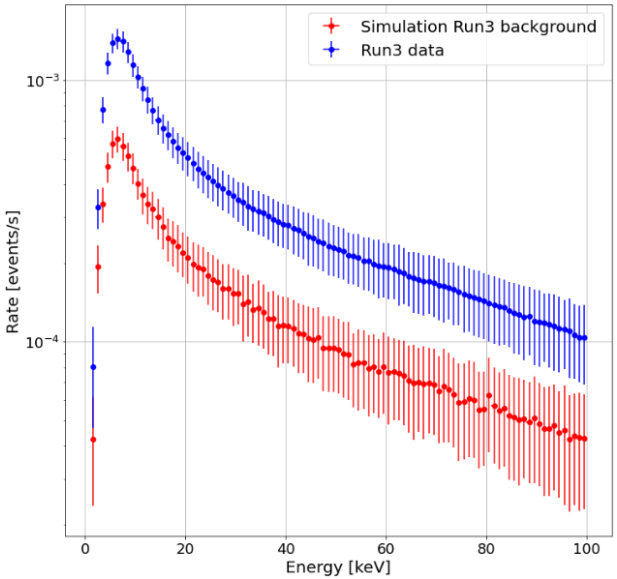
What about μ_b

- With Stefano we estimated a roughly 25 days of effective exposure time already available for LIME

↓

So time exposures tested: 25, 30, 45, 60 days

- The rate of Run3 was thoroughly analysed by Flaminia, so I started from here



This includes geometrical cuts on sides of the detector → **0.027 m^3 of sensitive volume**

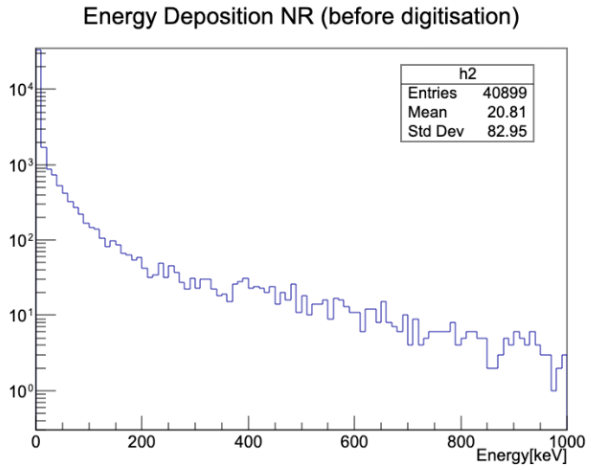
To match Run4, the histogram is scaled down by a factor 1,7 (ratio of measured rates between Run3 and 4)

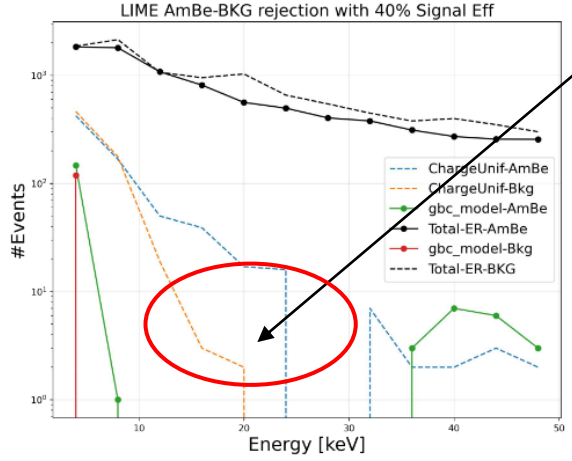
What about μ_b

- Energy threshold is applied here to cut all events below it
- Then application of rejection factor

Atul's one is considered too optimistic

- From AmBe simulation and Atul's application of rejection





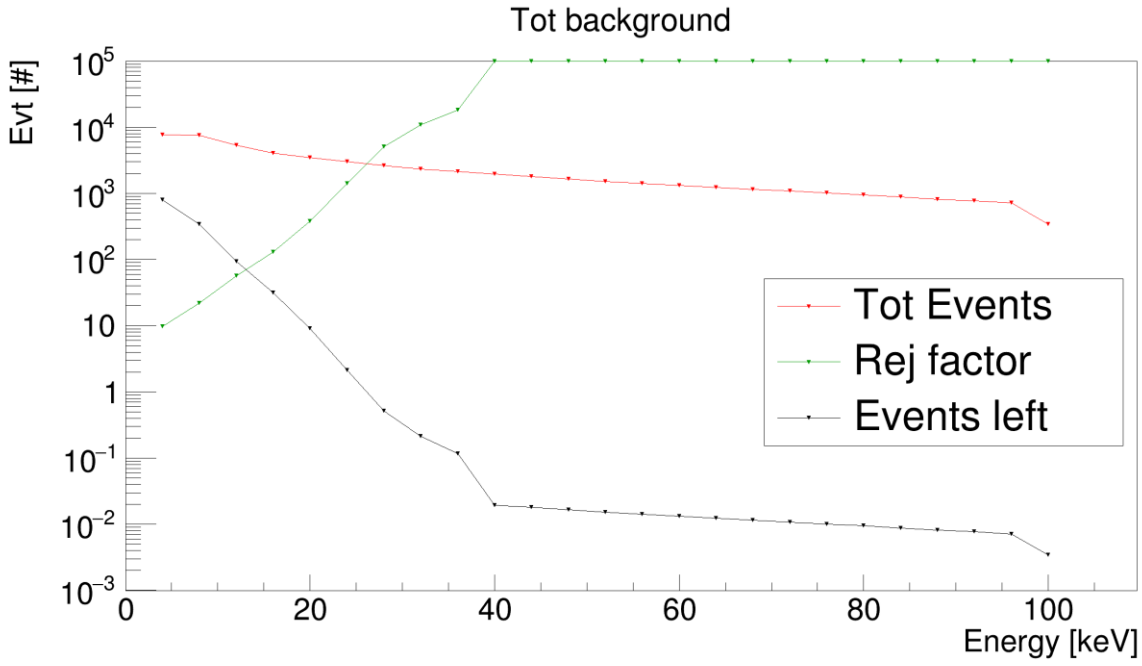
There should be events here if signal efficiency were 40%

Rejection could be overestimated in this range

What about μ_b

- Thus I used this rejection factor (keeping the assumption of 40% signal efficiency)

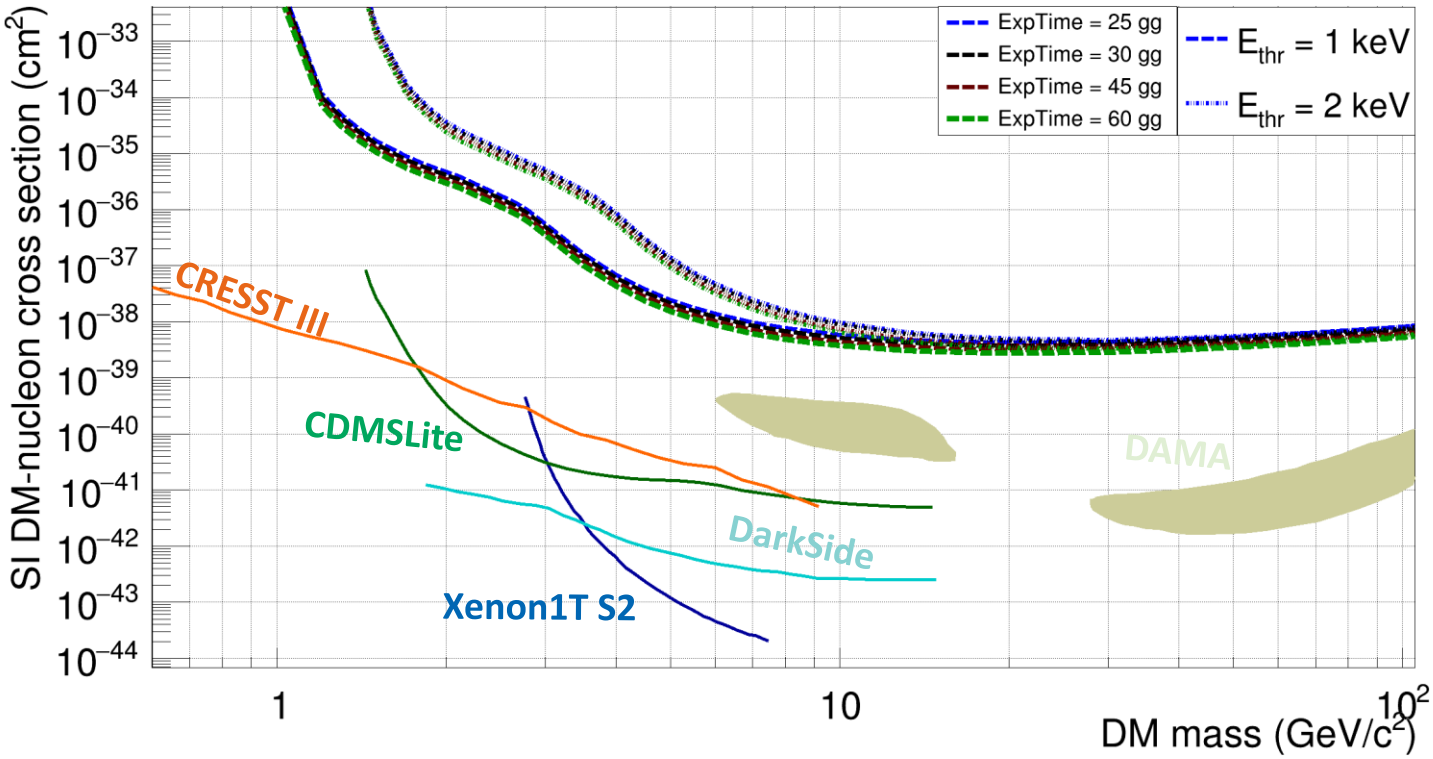
- Same as Atul's at 4 keV and at 40 keV. Worse in the middle (but better than non-machine learning techniques)



25 days (1 keV_{ee})	1273 bkg evt	25 days (2 keV_{ee})	1176 bkg evt
30 days (1 keV_{ee})	1527 bkg evt	30 days (2 keV_{ee})	1411 bkg evt
45 days (1 keV_{ee})	2292 bkg evt	45 days (2 keV_{ee})	2118 bkg evt
60 days (1 keV_{ee})	3059 bkg evt	60 days (2 keV_{ee})	2827 bkg evt

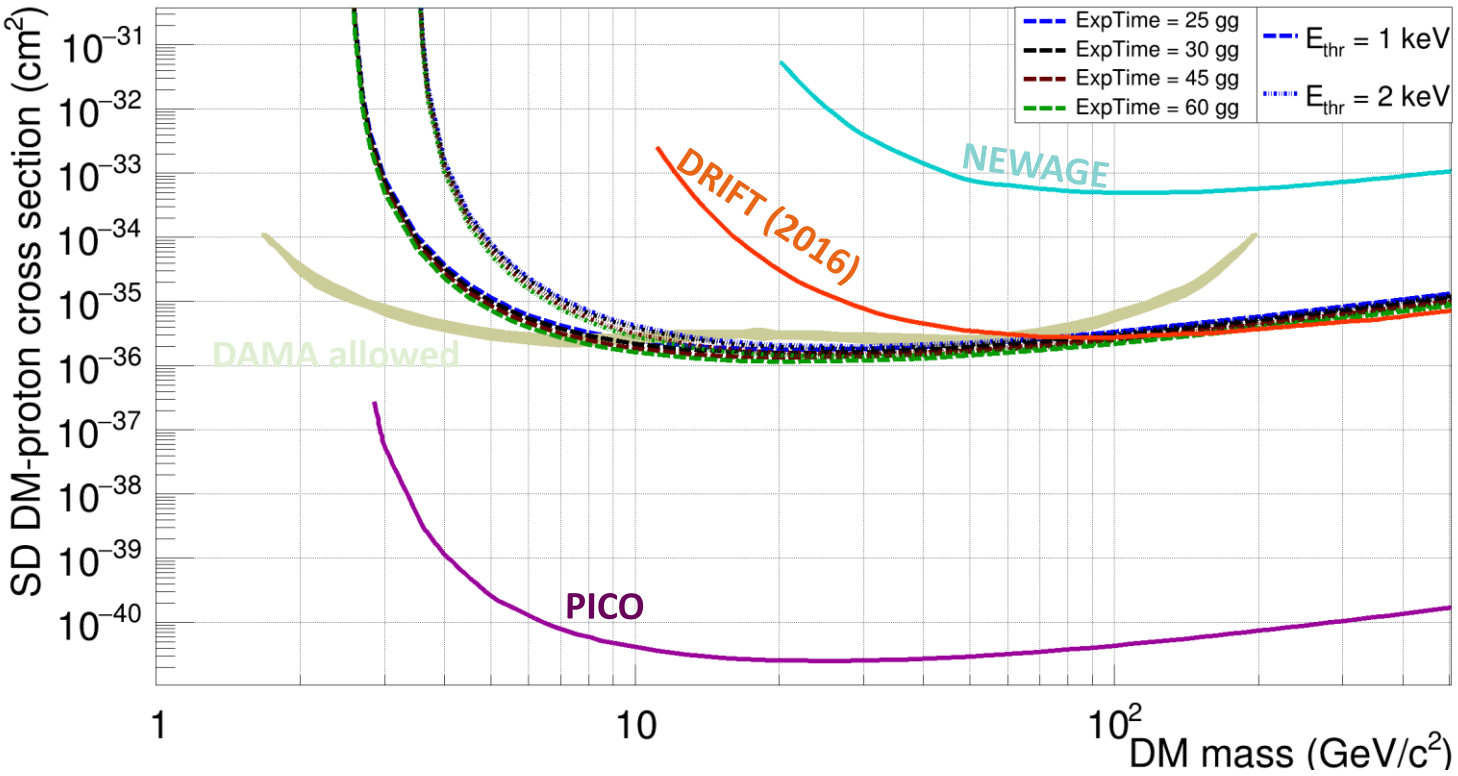
SI

- The average on 100 repetitions yielded a 10% uncertainty on the limits, well within line width



- DAMA not reached (it would need 50 times more exposure)
- 2 keV_{ee} threshold is not better even with lower background

SD

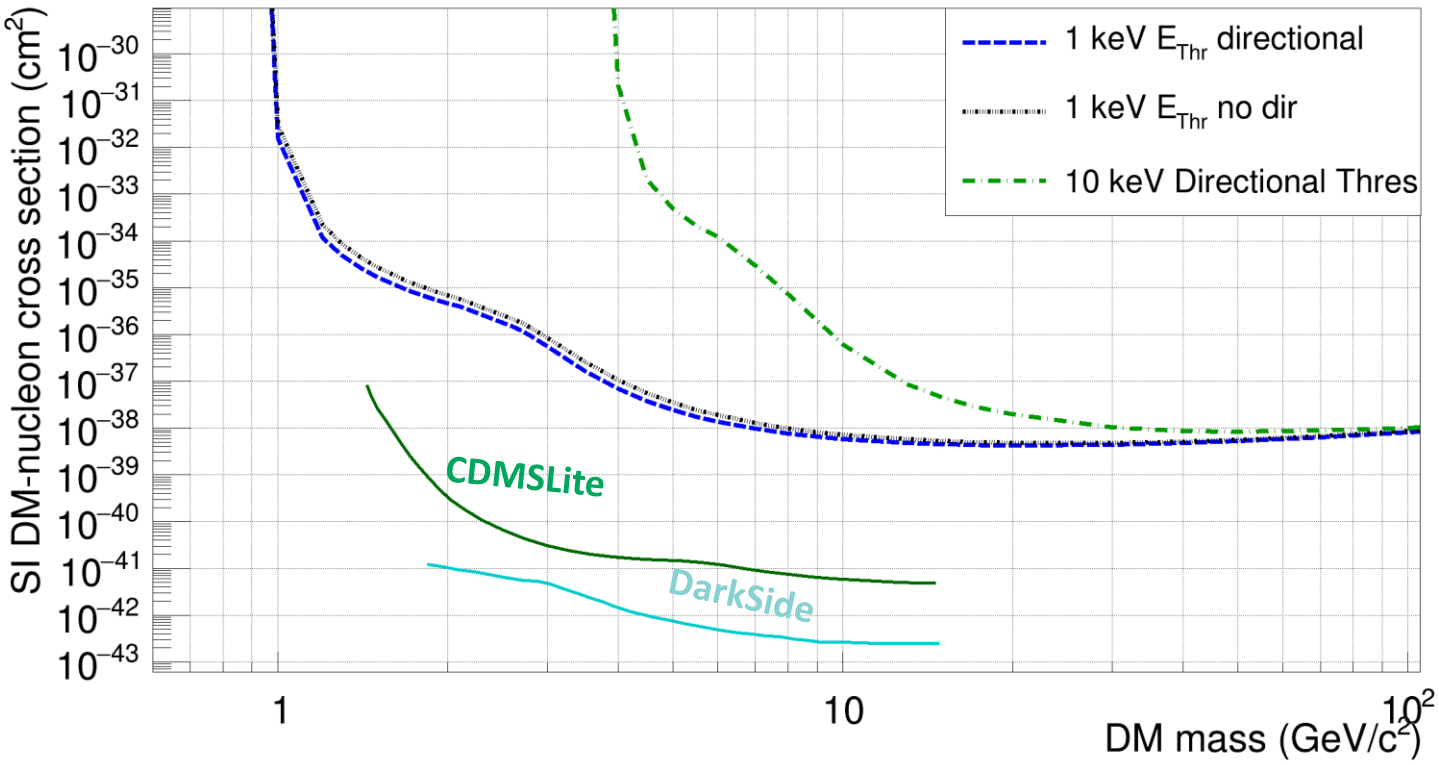


- DAMA reached
- 2 keV_{ee} threshold is not better even with lower background
- Better (similar at large masses) than other directional

SI directional?

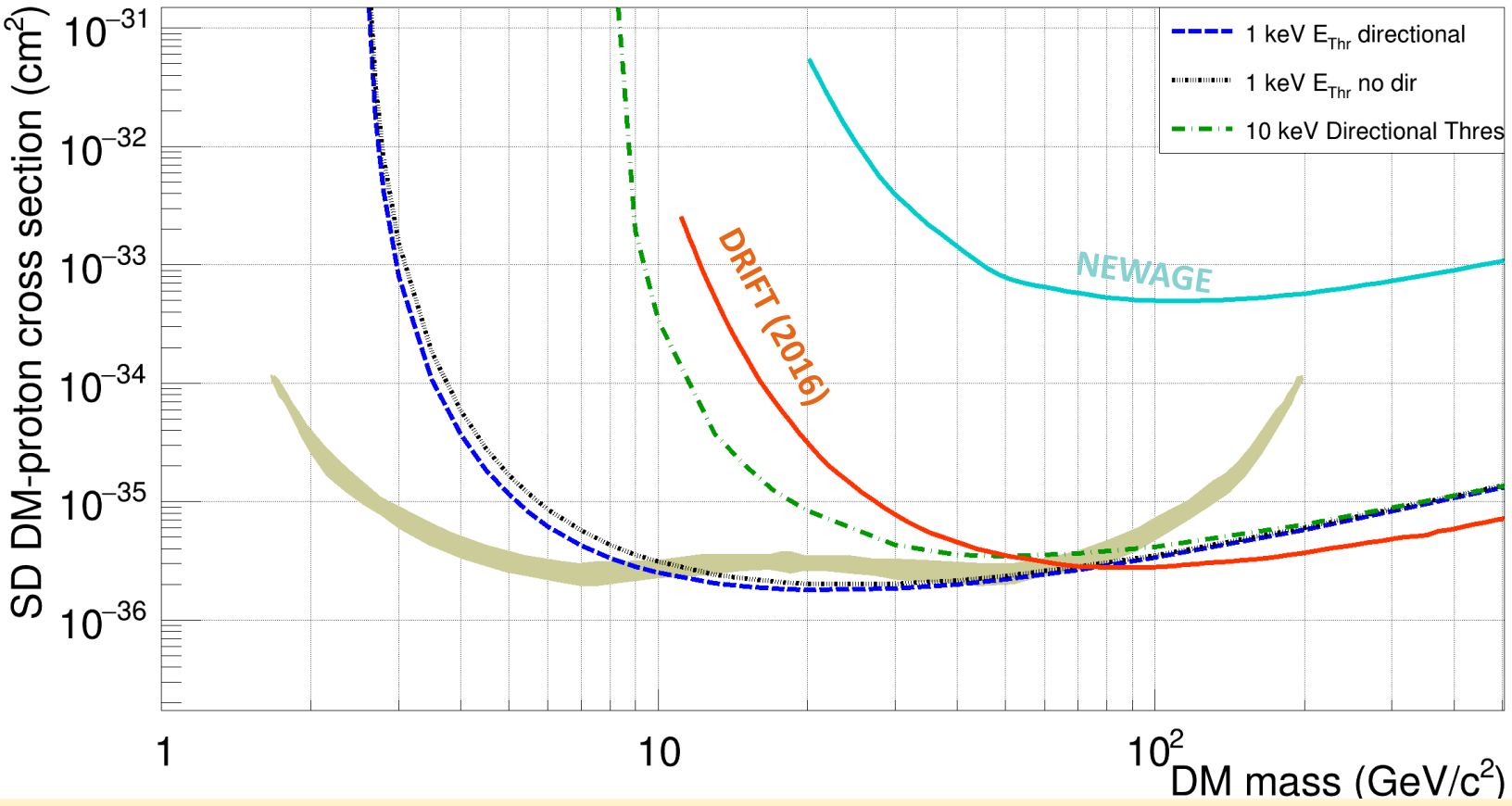
- The biggest assumption is that directionality is kept down to the energy threshold. What if no directional information is available?

  Where is the detector actually acting as directional detector? 10 keV_{ee}?



SD directional?

- Similar to SD



Main takeaways

- Limits will need to be done better from the point of view of the experimental effect and adding the energy information
- The true ones will be very likely worse at low WIMP masses
- Increasing the time of exposure of Run4 has an improvement on the limit of a factor 1,6 (slightly better than sqrt(2)) but in reasonable time no great achievement seems to be reacheable
- While on the limit itself, the directional information helps ‘’only’’ of a factor 2, where the detector is actually directional plays a big role on the physics reach
- Could this suggest a gas tight vessel for CYGNO-04 to maybe lower pressure (factor 2) and reduce the directional threshold?