Status of Sensitivity Projections

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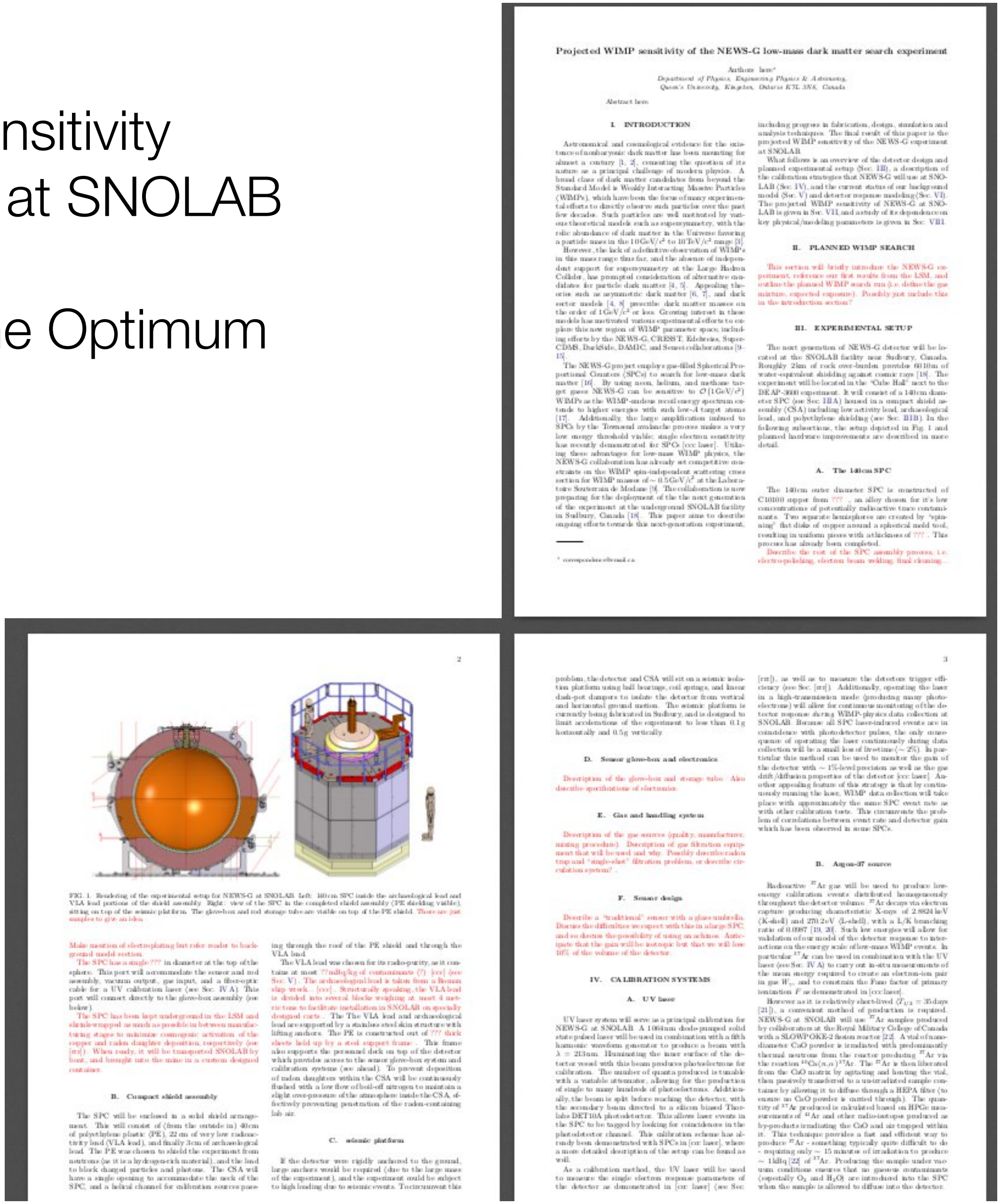
June 12th 2019
NEWS-G Collaboration Meeting
Grenoble, France

Current status

We have our nominal WIMP sensitivity projections for Ne + 10% CH4 at SNOLAB

Our limits are produced with the Optimum Interval method

A possible paper on this was in preparation (>50% written)



Projected WIMP sensitivity of the NEWS-G low-mass dark matter search experiment

Authors here*

Department of Physics, Engineering Physics & Astronomy,
Queen's University, Kingston, Ontario K7L 3N6, Canada

Abstract here

I. INTRODUCTION

II. PLANNED WIMP SEARCH

Current status

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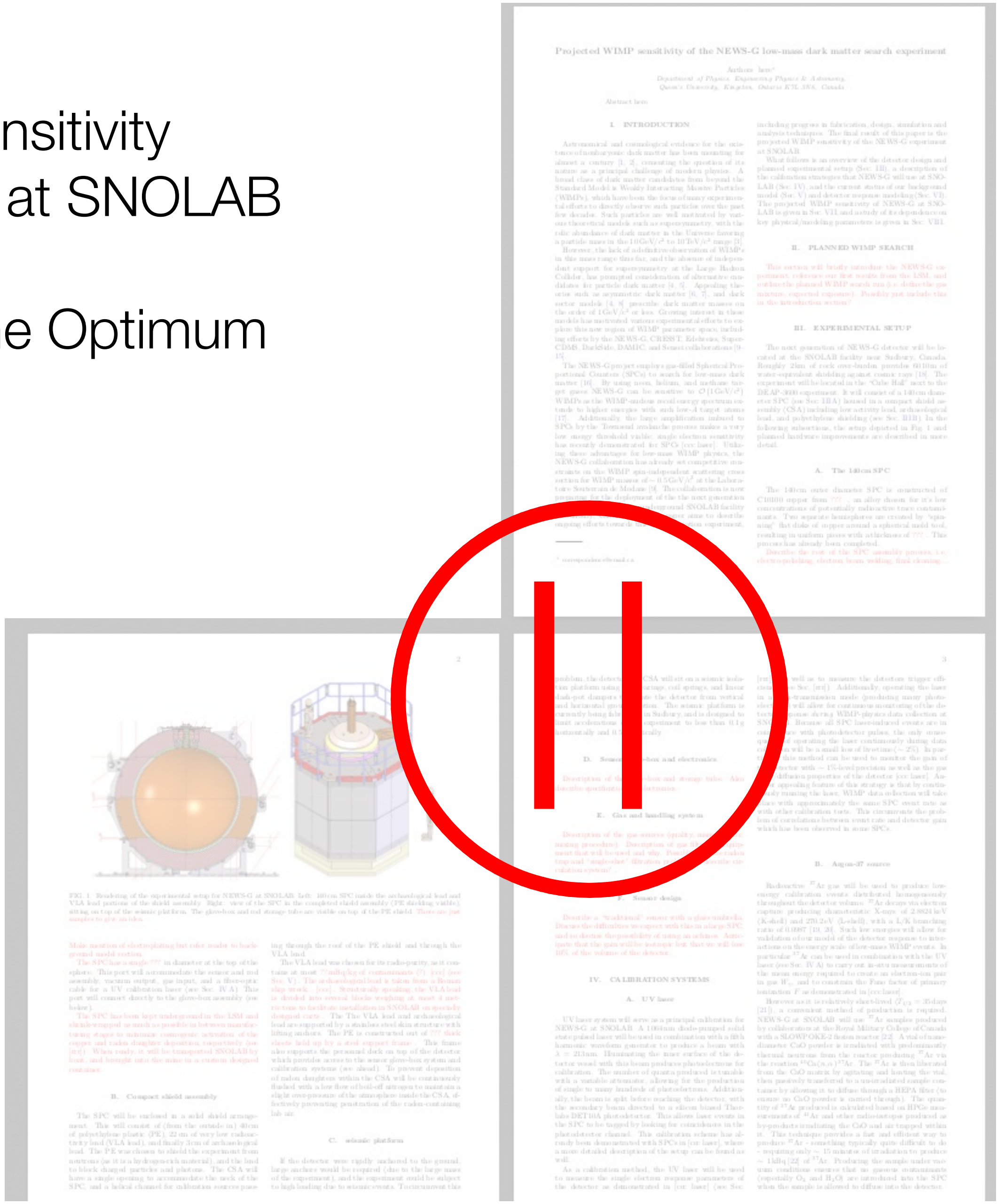

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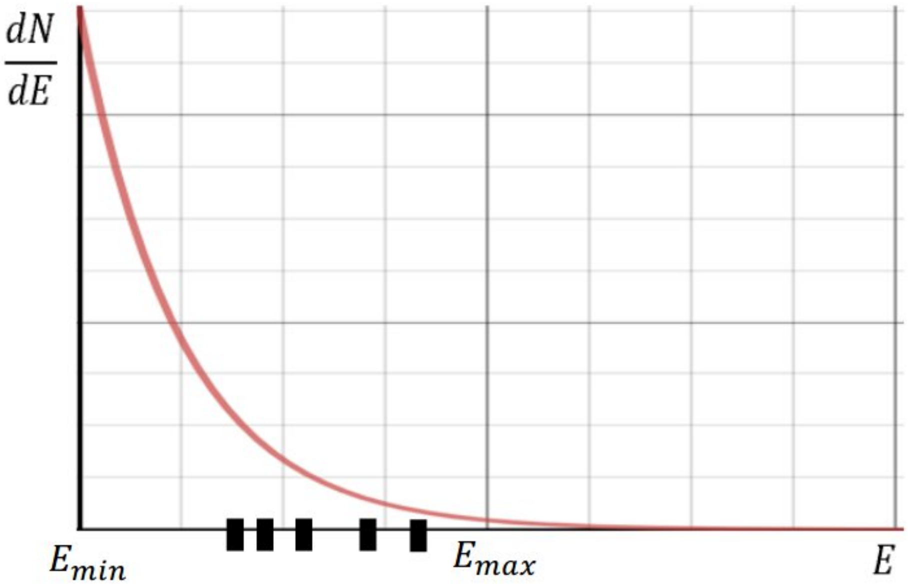
Abstract here

Put on hold over concerns about our ill-understood low-energy background, proximity to physics results...

The Optimum Interval method

Yellin's method (thanks Alan) uses the shape of the expected signal to find the sub-range of parameter space that allows for the best sensitivity

"Looking" at the data incurs a statistical penalty

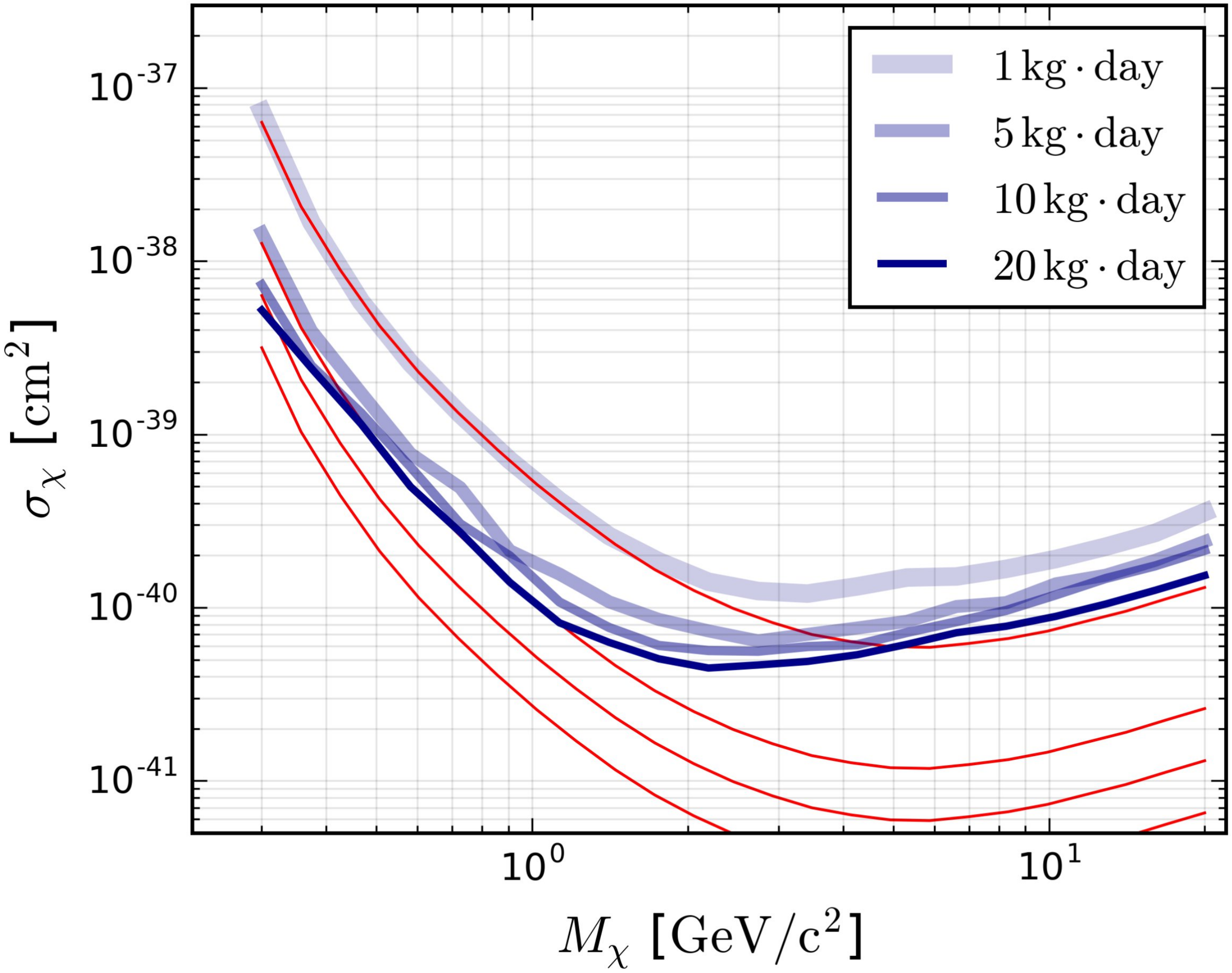


	Poisson	Optimum Interval	Profile $\mathcal{L}$ Ratio
Uses background information	✗	✗	✓
Uses Signal information	✗	✓	✓

(We don't yet understand our background well enough to use a likelihood analysis)

The Optimum Interval method

The Optimum Interval method allows us to recover much of our sensitivity, especially at low WIMP masses



OI Limits

Corresponding Background Free Limits

- Neon, 1 kg.day
- Flat background (3 dru$_{ee}$)
- F = 0.2, θ=0, SRIM Q
- 100 trials
- ROI of 36 eV$_{ee}$ -1 keV$_{ee}$

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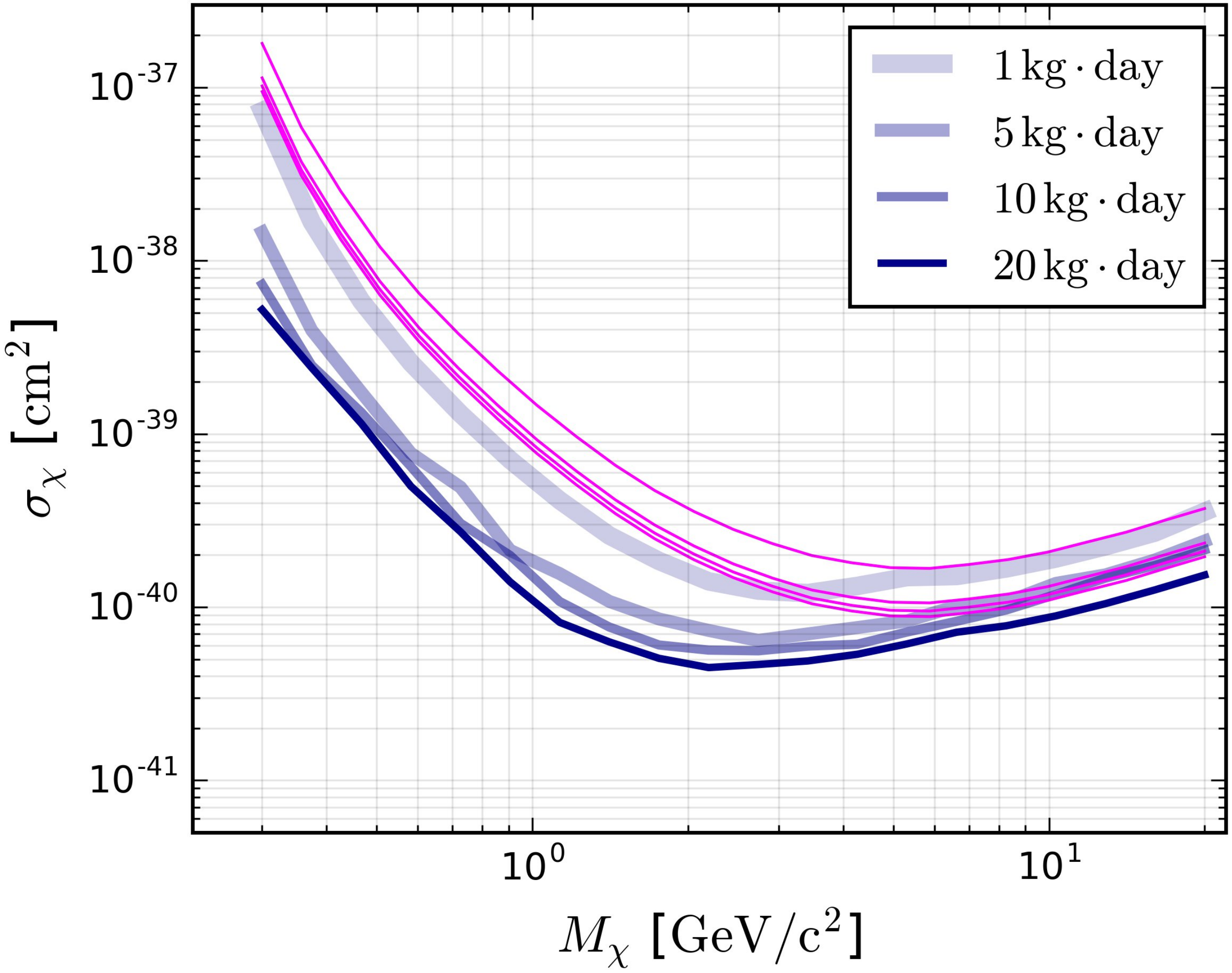
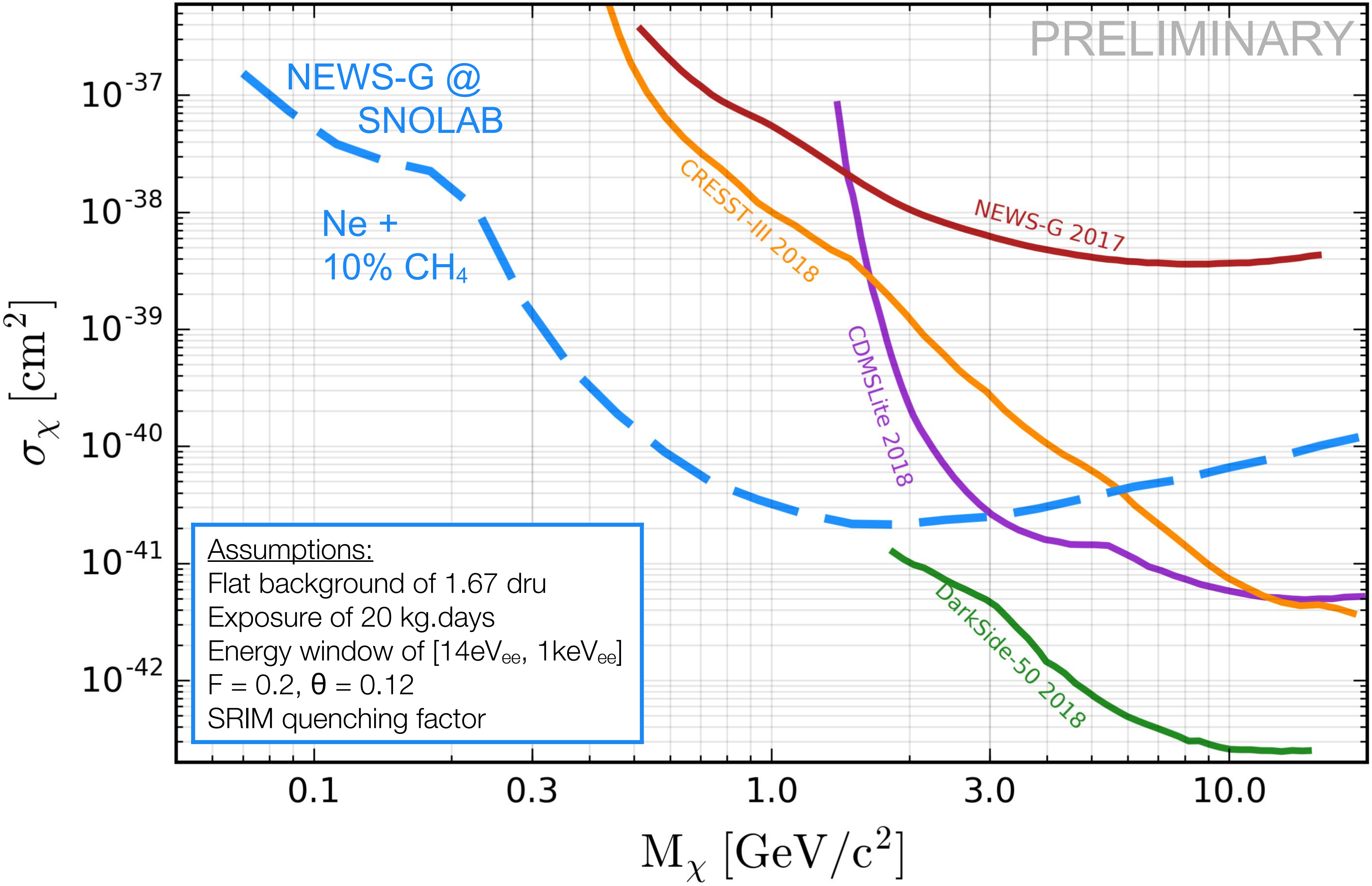


OI Limits

Corresponding Poisson Limits

- Neon, 1 kg.day
- Flat background (3 $\mathrm{dru_{ee}}$)
- F = 0.2, θ=0, SRIM Q
- 100 trials
- ROI of 36 $\mathrm{eV_{ee}}$ -1 $\mathrm{keV_{ee}}$

Our nominal projection for NEWS-G @ SNOLAB

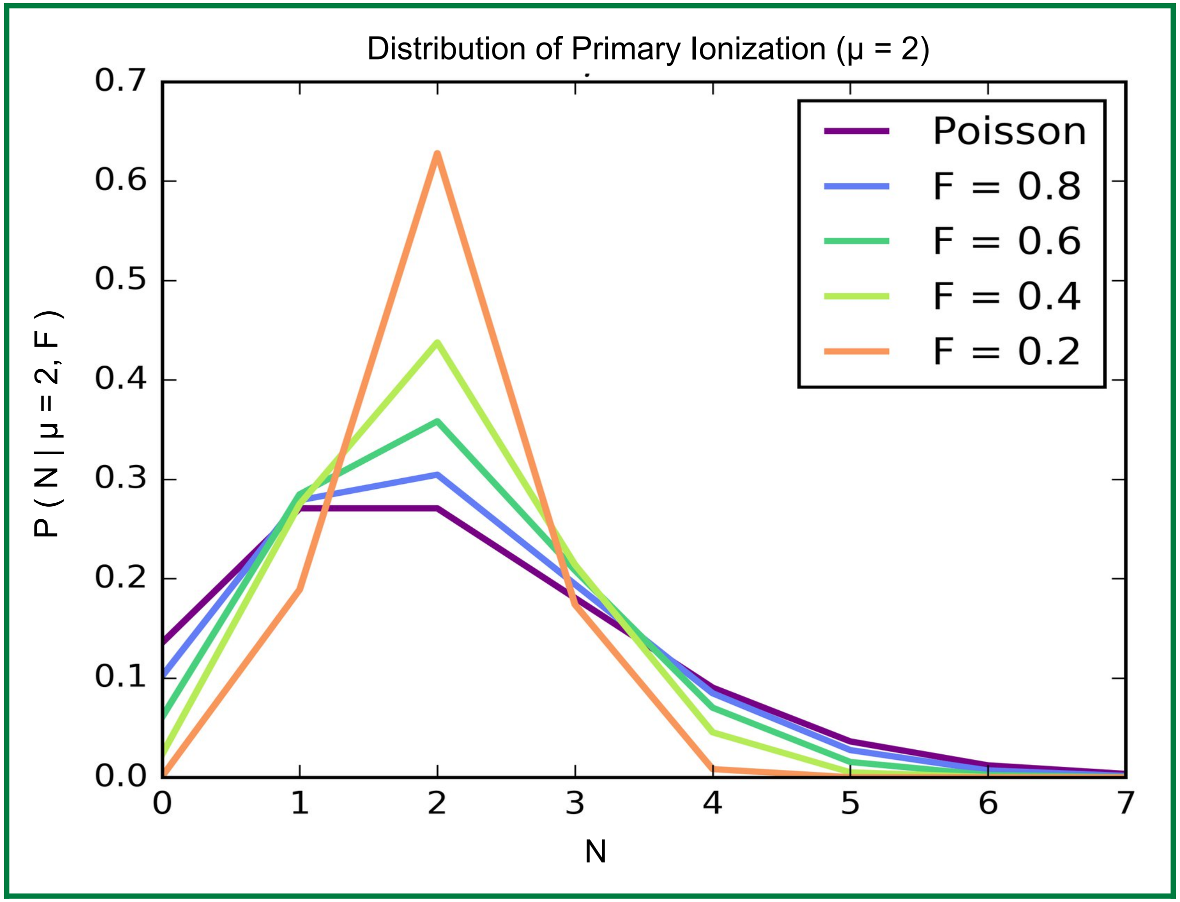


Assumptions:
Flat background of 1.67 dru
Exposure of 20 kg.days
Energy window of [$14eV_{ee}$, $1keV_{ee}$]
F = 0.2, θ = 0.12
SRIM quenching factor

Trigger efficiency measurements

Our detector response model assumes:

» COM-Poisson for primary ionization



Trigger efficiency measurements

Our detector response model assumes:

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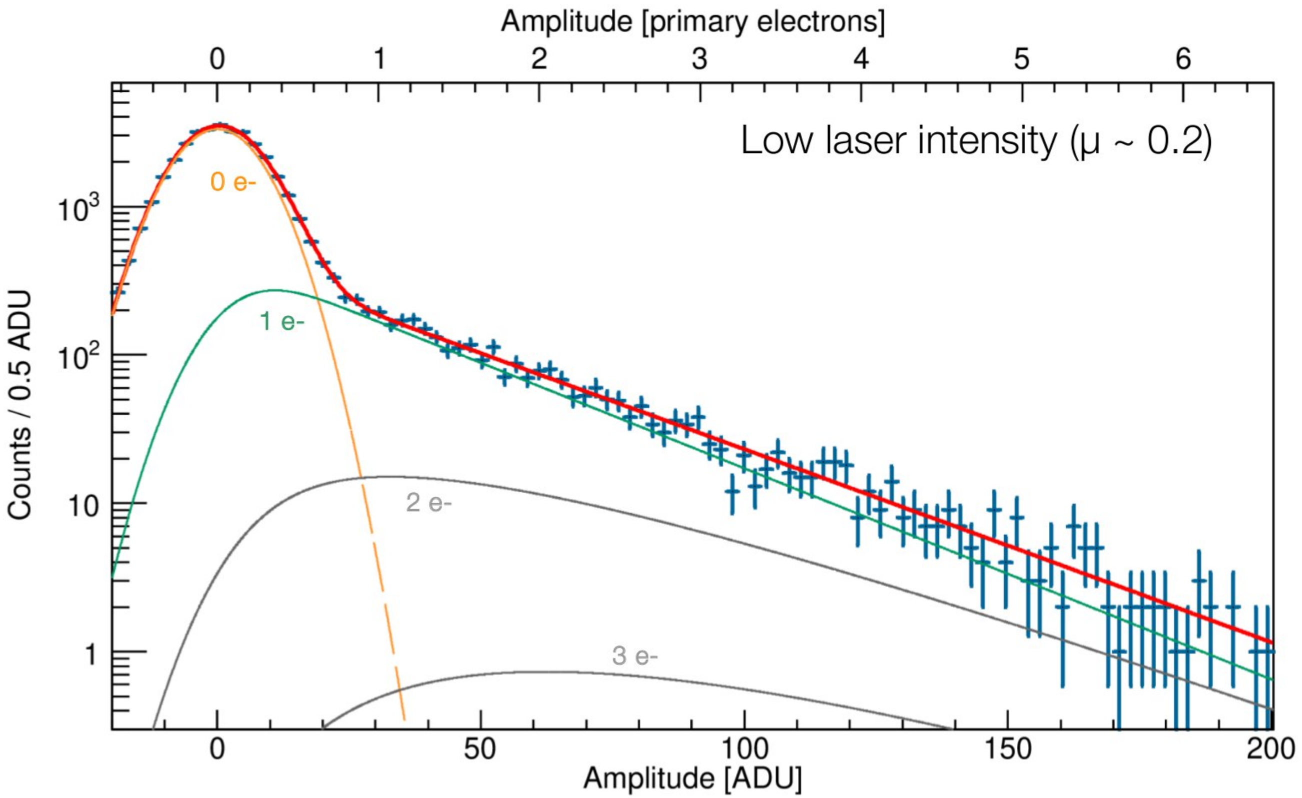
Trigger efficiency measurements

Our detector response model assumes:

» COM-Poisson for primary ionization

» SRIM quenching factor

» Nth Polya for avalanche response



Q. Arnaud et al. (NEWS-G), Phys. Rev. D 99, 102003 (2019)

Trigger efficiency measurements

Our detector response model assumes:

» COM-Poisson for primary ionization

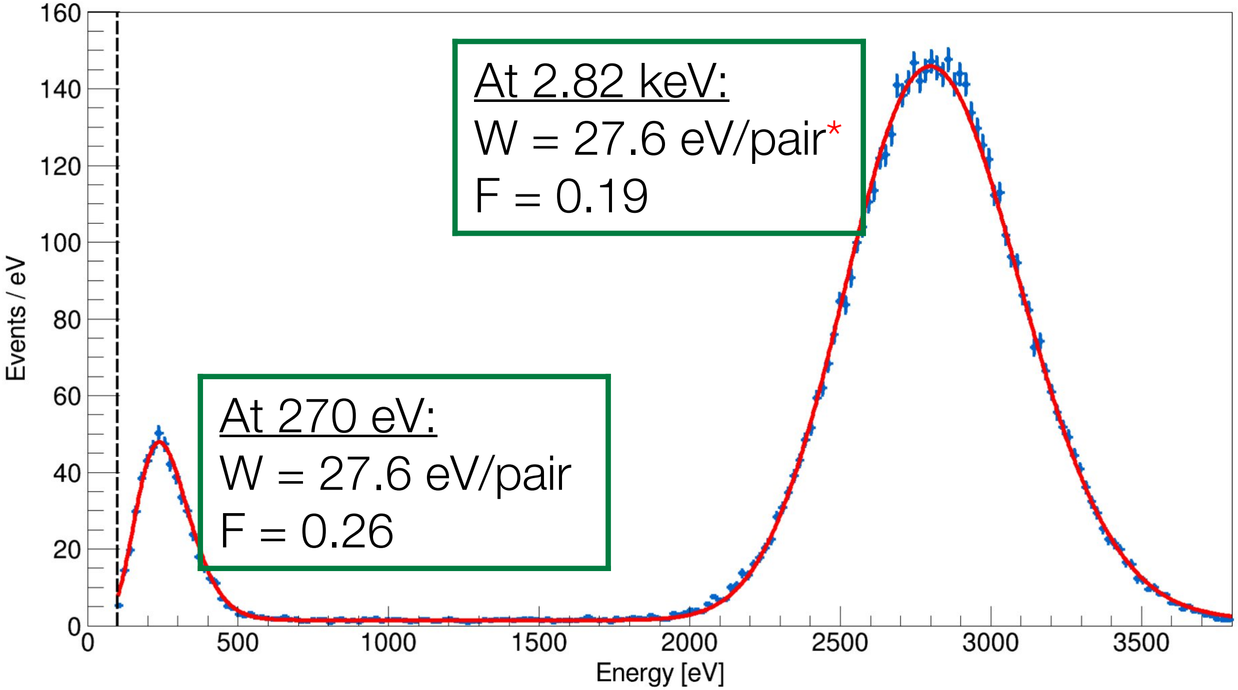
» SRIM quenching factor

» Nth Polya for avalanche response

» Laser or Laser + 37Ar measurements of θ, <G>, W-value, F

$$f\left(E'\right) = \sum_{N=1}^{N_{\max}} P_{\mathrm{CMP}}\left(N|\mu, F\right) \times P_{\mathrm{Polya}}^{(\mathrm{N})}\left(E'|\left\langle G\right\rangle, \theta\right)$$

Best-fit values



*The W-value at 2.82 keV was calculated directly from <G> and fixed for this fit

Q. Arnaud et al. (NEWS-G), Phys. Rev. D 99, 102003 (2019)

Trigger efficiency measurements

Our detector response model assumes:

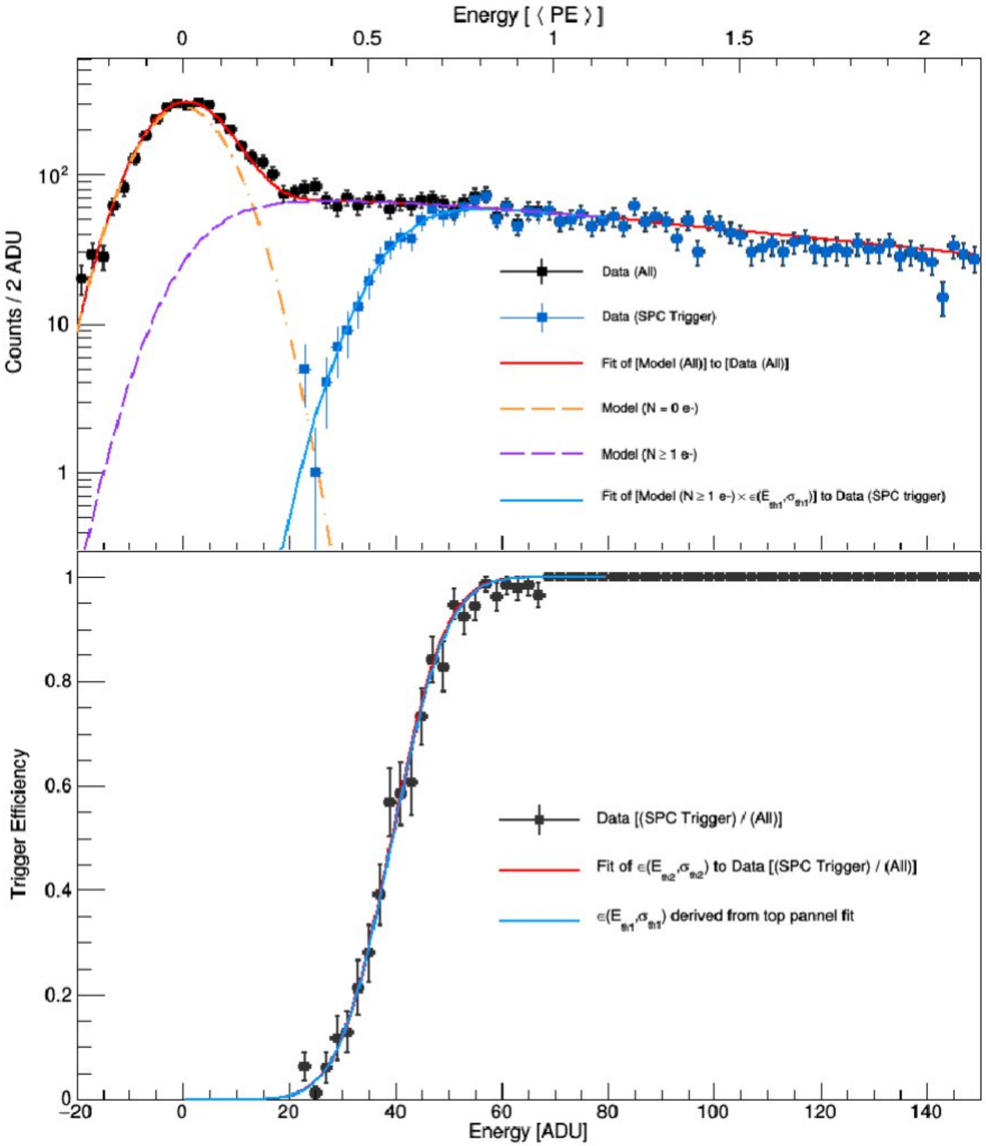
» COM-Poisson for primary ionization

» SRIM quenching factor

» Nth Polya for avalanche response

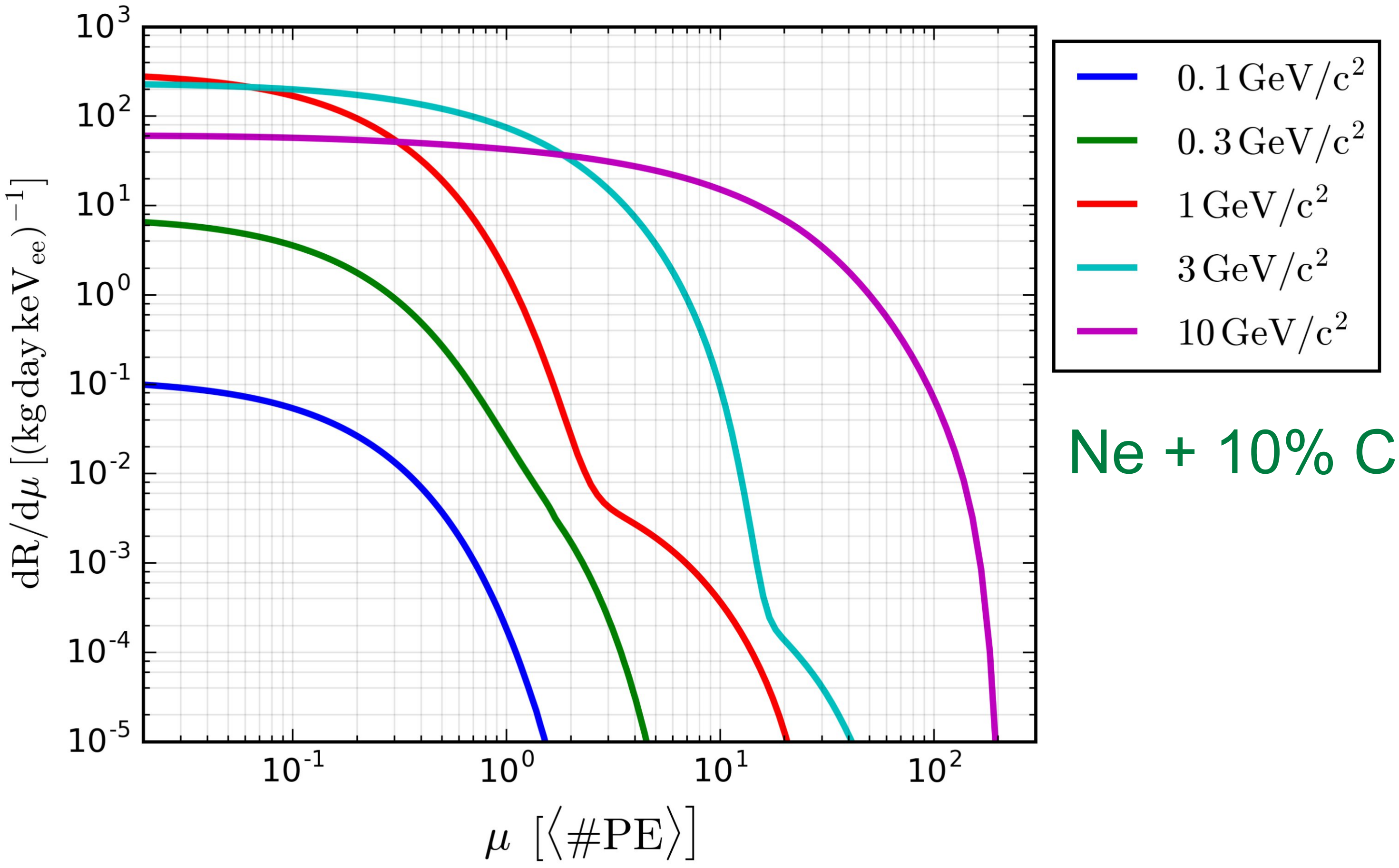
» Laser or Laser + 37Ar measurements of θ, <G>, W-value, F

» Trigger efficiency energy threshold driven by laser measurements



Q. Arnaud et al. (NEWS-G), Phys. Rev. D 99, 102003 (2019)

Energy response model



Ne + 10% CH_4

$$\frac{dR}{dE}(E_{ee}) = \int_0^{E_{\max}} \frac{dR}{dE}(E_{nr}) \times \sum_{N=0}^{N_{\max}} \left[P_{\mathrm{COM}}\left(N|\mu, F\right) \times P^{(N)}_{\mathrm{Polya}}\left(E_{ee}|\theta, \langle G \rangle\right)\right] dE_{nr}$$

$$\mu = E_{nr} \times \left(\frac{Q(E_{nr})}{W(E_{nr})} \right) \qquad N_{\max} = \left\lfloor \frac{E_{nr}}{I} \right\rfloor$$

Considering a pure CH_4 run

What is the physics advantage of a pure 200 mbar CH_4 run?

Given time constraints at the LSM, it might be advantageous:

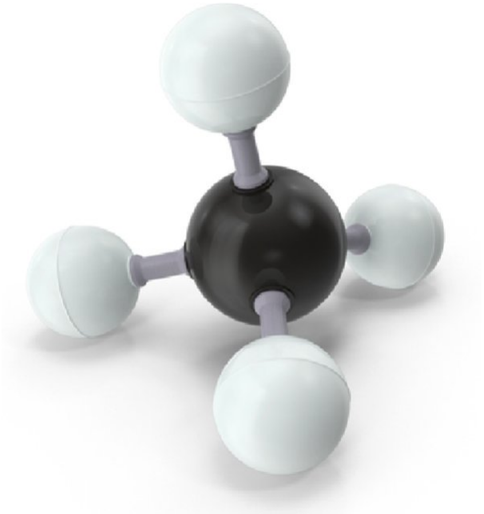
» The proportion of hydrogen is greater per unit mass of gas

» Slightly higher background $kg^{-1}day^{-1}$ (ask Alexis), but lower background rate $kg^{-1}day^{-1}$ of H than 2 bar of Ne + 10% CH_4

» Greater sensitivity to low-mass WIMPs for given exposure

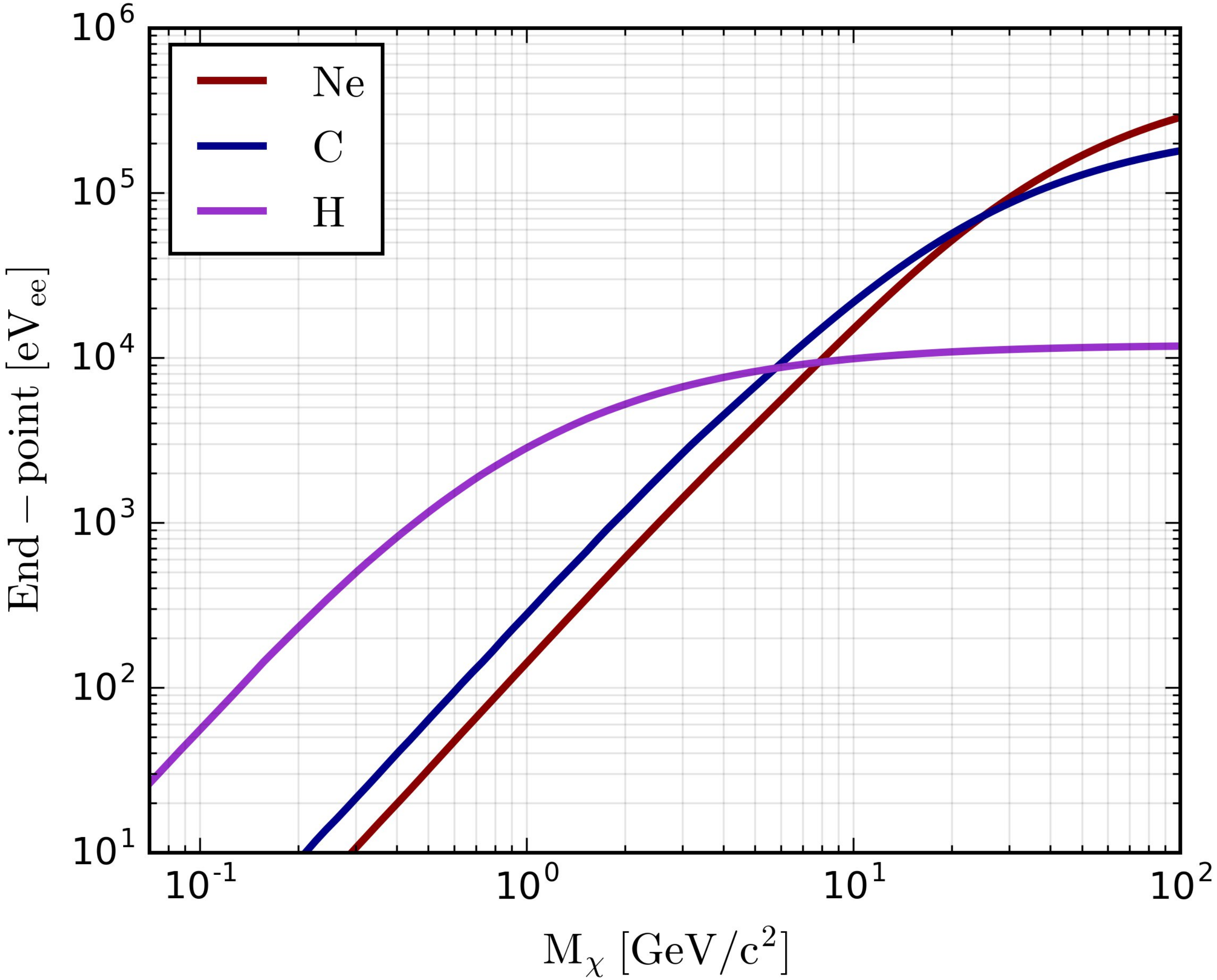
» Quenching factor measurements from Grenoble t.b.p. soon?

» W-value known for pure methane, no need to worry about characterizing Penning transfers in gas mixtures



The impact of carbon

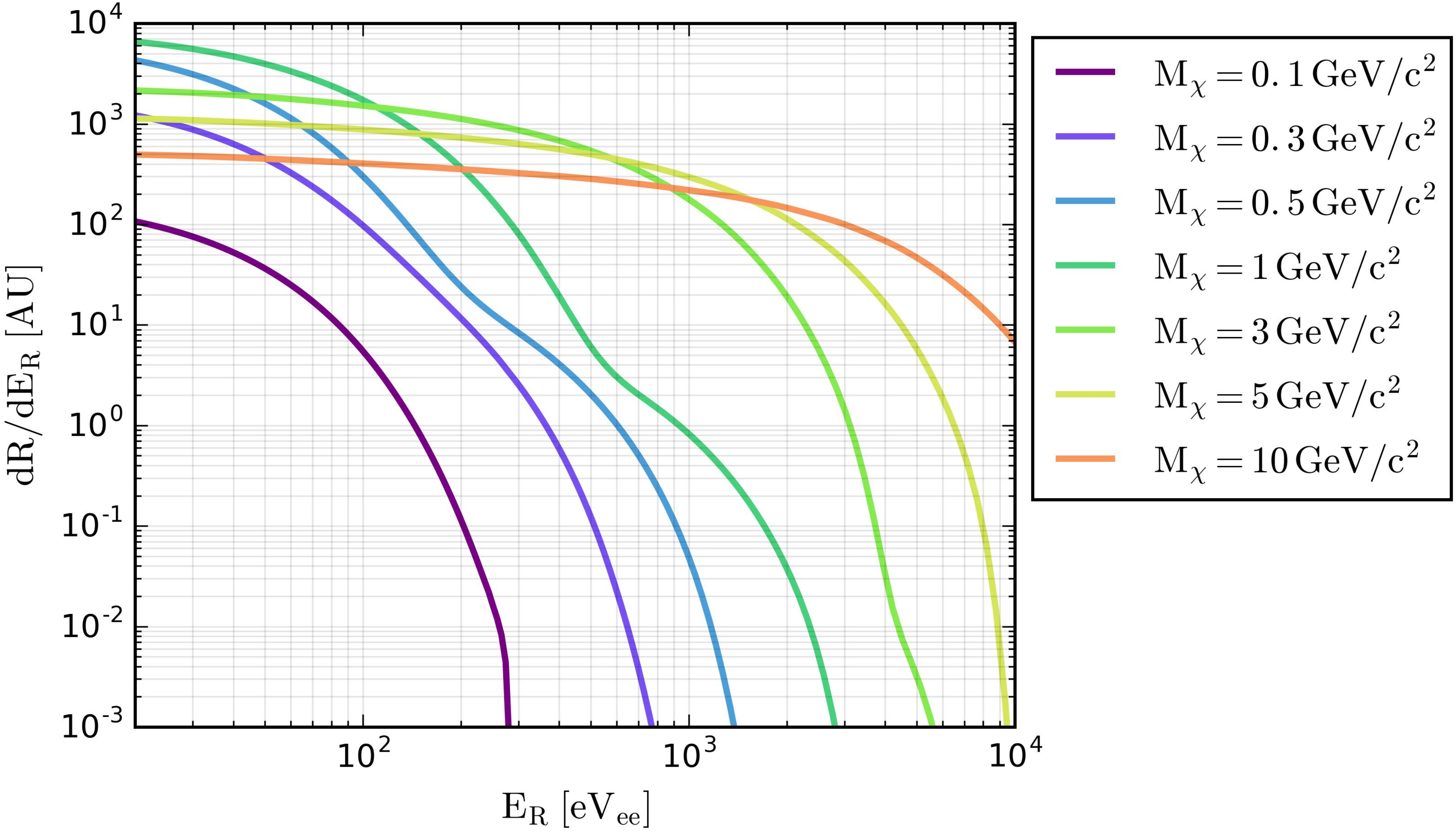
I haven't had a chance yet to write code include carbon in the Ne + CH_4 limit code
(it is not super easy)



In any case, the impact of carbon in this limit will be very small (possibly completely invisible)

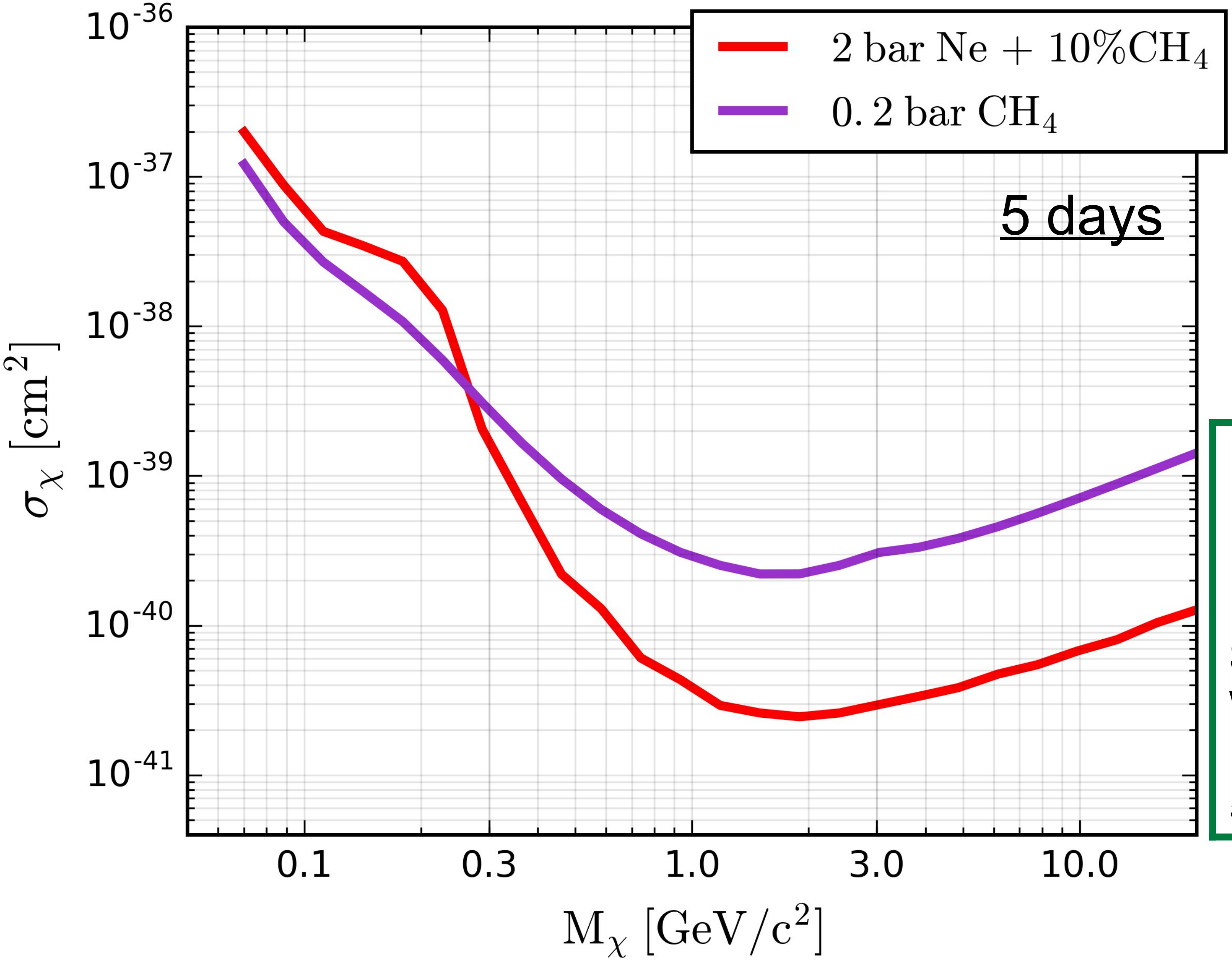
The impact of carbon

The code for pure CH_4 works! Carbon almost replaces Neon in this case



Possible structure of paper

The Neon limit is immediately background-limited, but the CH_4 limit is not



Flat background
1.67±0.5 dru for Ne
1.7±0.5 dru for CH_4
F = 0.2, θ=0.12
SRIM Q
W = 28 eV
14 eV_{ee} -1 keV_{ee}
500 trials

Possible structure of paper

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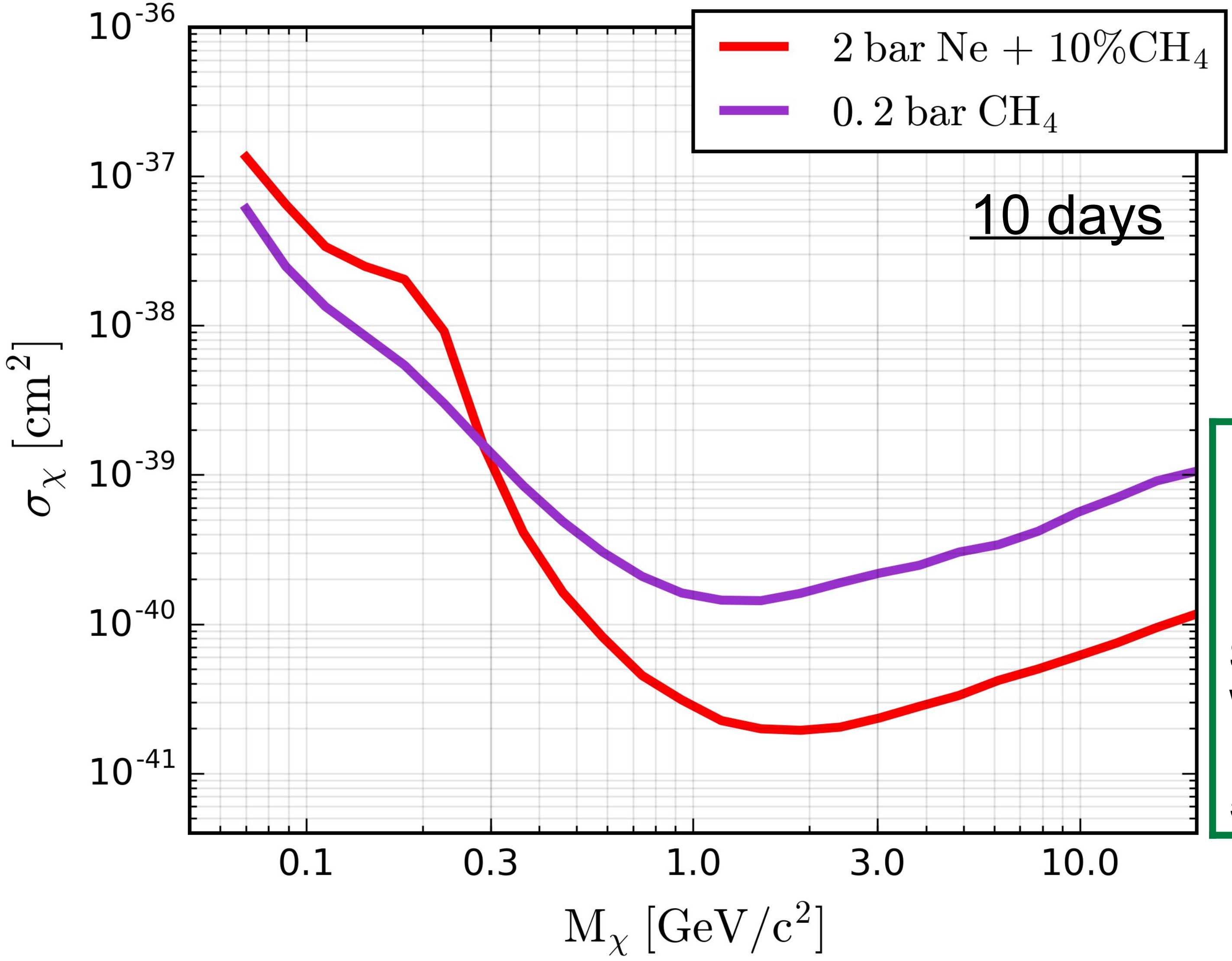

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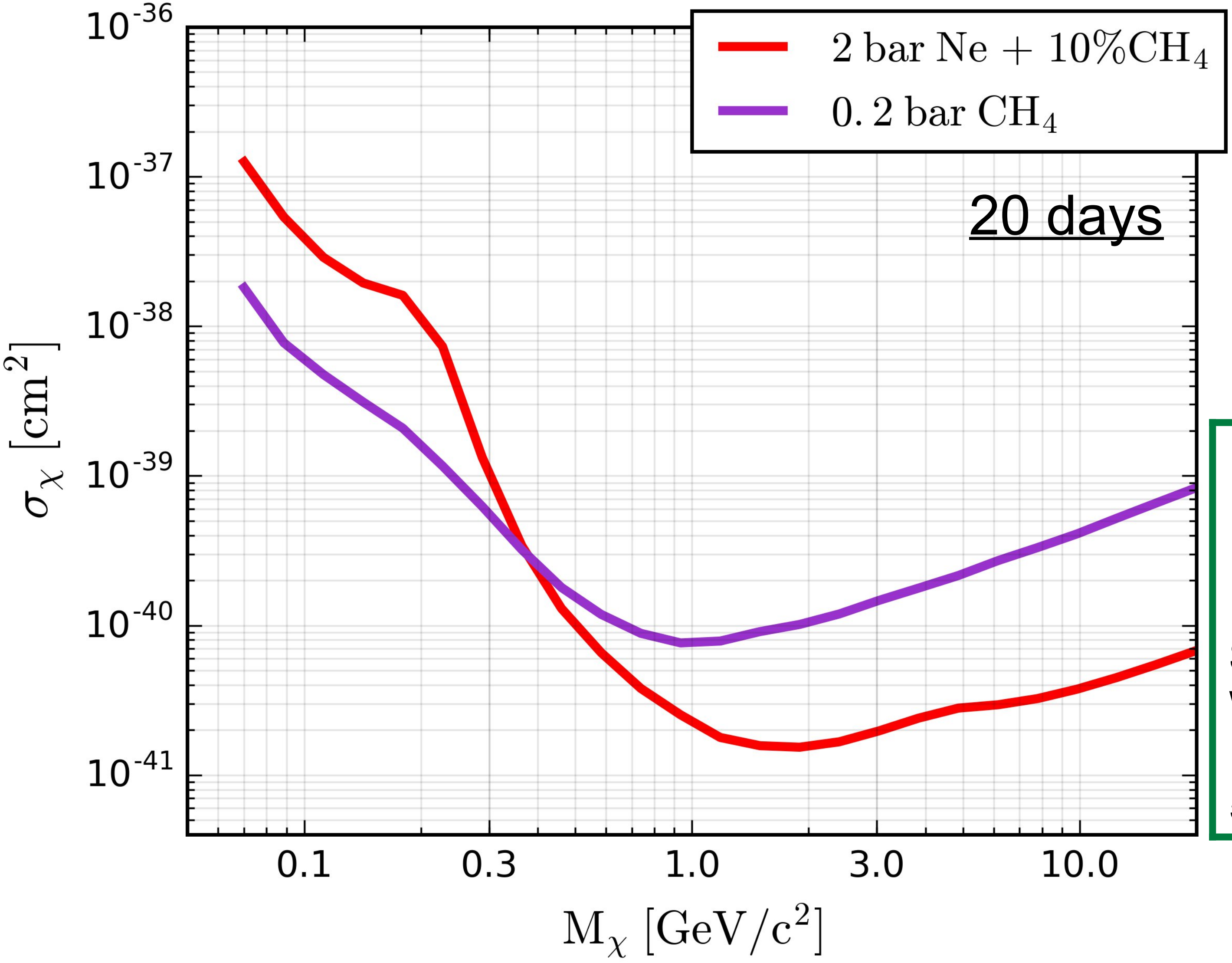

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500 trials

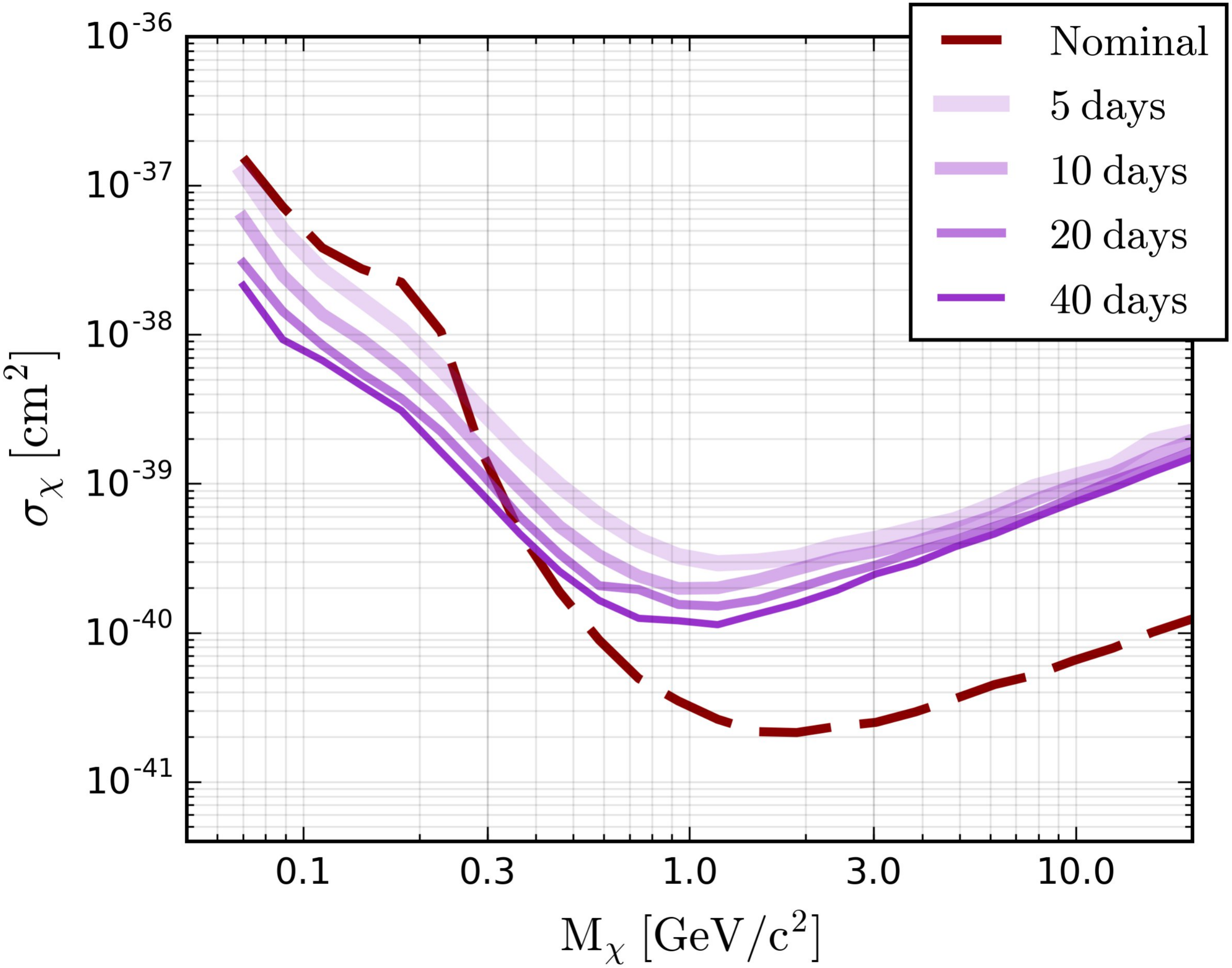
Possible structure of paper

The Neon limit is immediately background-limited, but the CH_4 limit is not

Data taking [days]	2 bar Ne+10% CH_4		200 mbar CH_4	
	Exposure [kg.days]	<#BE>	Exposure [kg.days]	<#BE>
5	11.5	18.9	0.93	3.16
10	22.9	37.7	1.86	6.32
20	45.8	75.4	3.72	12.6
40	91.6	151	7.44	25.3

Possible structure of paper

But something else to keep in mind: Higher background from cosmogenics while at the LSM (~3.4 dru, ask Alexis)



2bar Ne+10% CH4
Flat background,
1.67±0.5
F = 0.2, θ=0.12
SRIM Q
W = 28 eV
14 eV_{ee} -1 keV_{ee}
500 trials

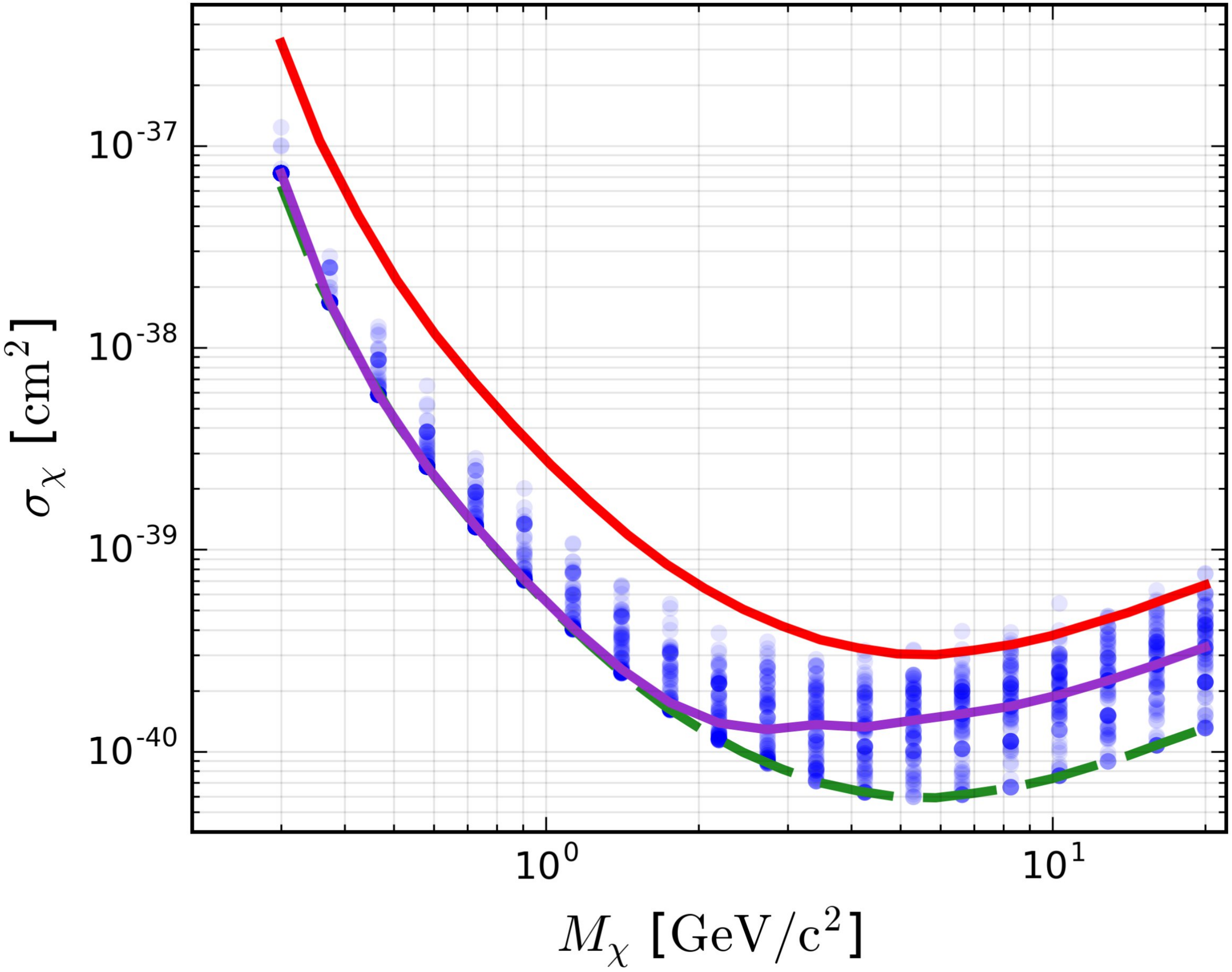
200mbar CH4
Flat background,
3.4±0.5
F = 0.2, θ=0.12
SRIM Q
W = 28 eV
14 eV_{ee} -1 keV_{ee}
500 trials

Thank you!

Extra Slides

Possible structure of paper

The Optimum Interval method allows us to recover much of our sensitivity, especially at low WIMP masses



OI - individual MCs

Median of OI

Poisson Limit

Background Free

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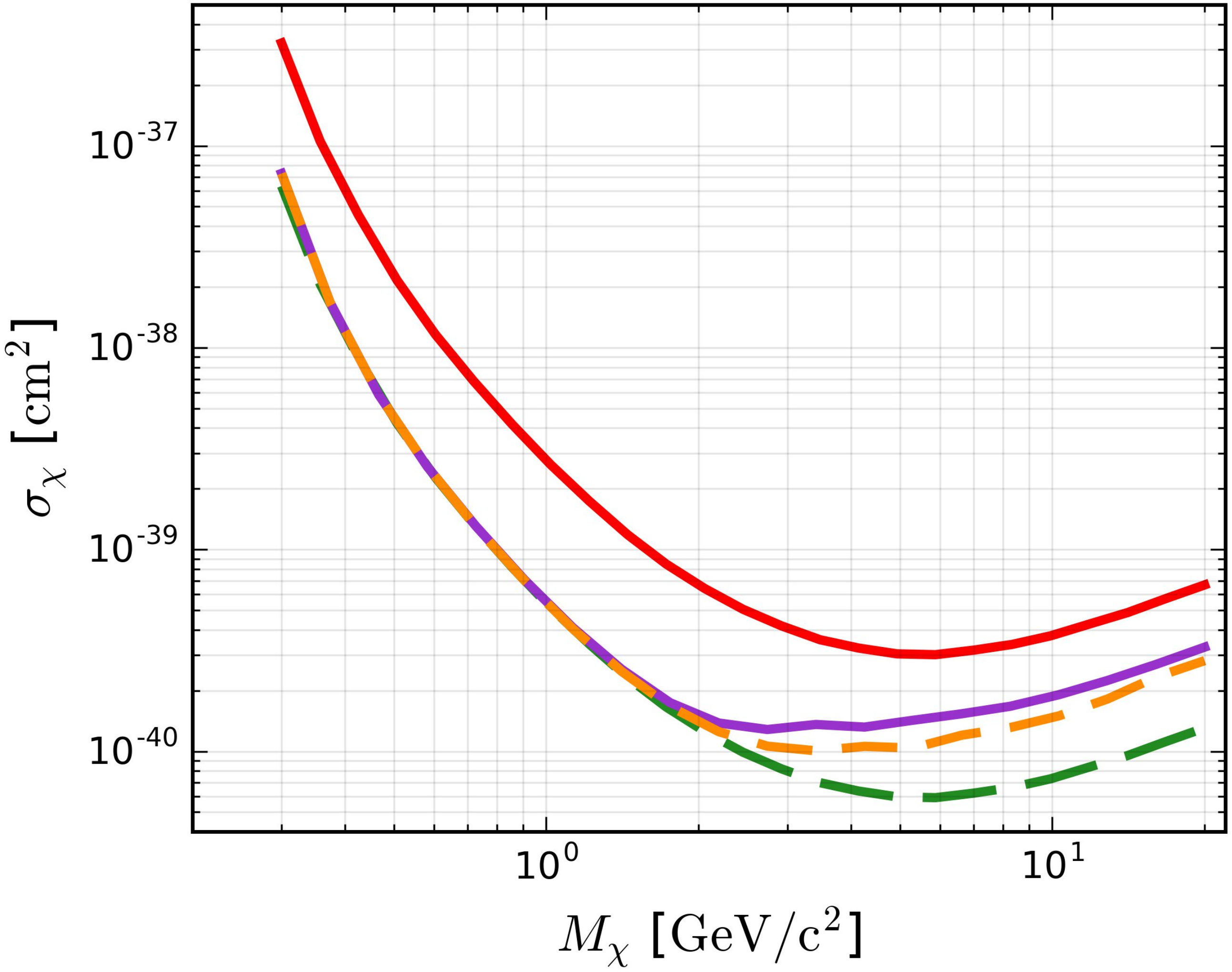
The Optimum Interval method allows us to recover much of our sensitivity, especially at low WIMP masses



Median Poisson on Optimum Interval
Median of OI
Poisson Limit
Background Free

- Neon, 1 kg.day
- Flat background (3 dru$_{ee}$)
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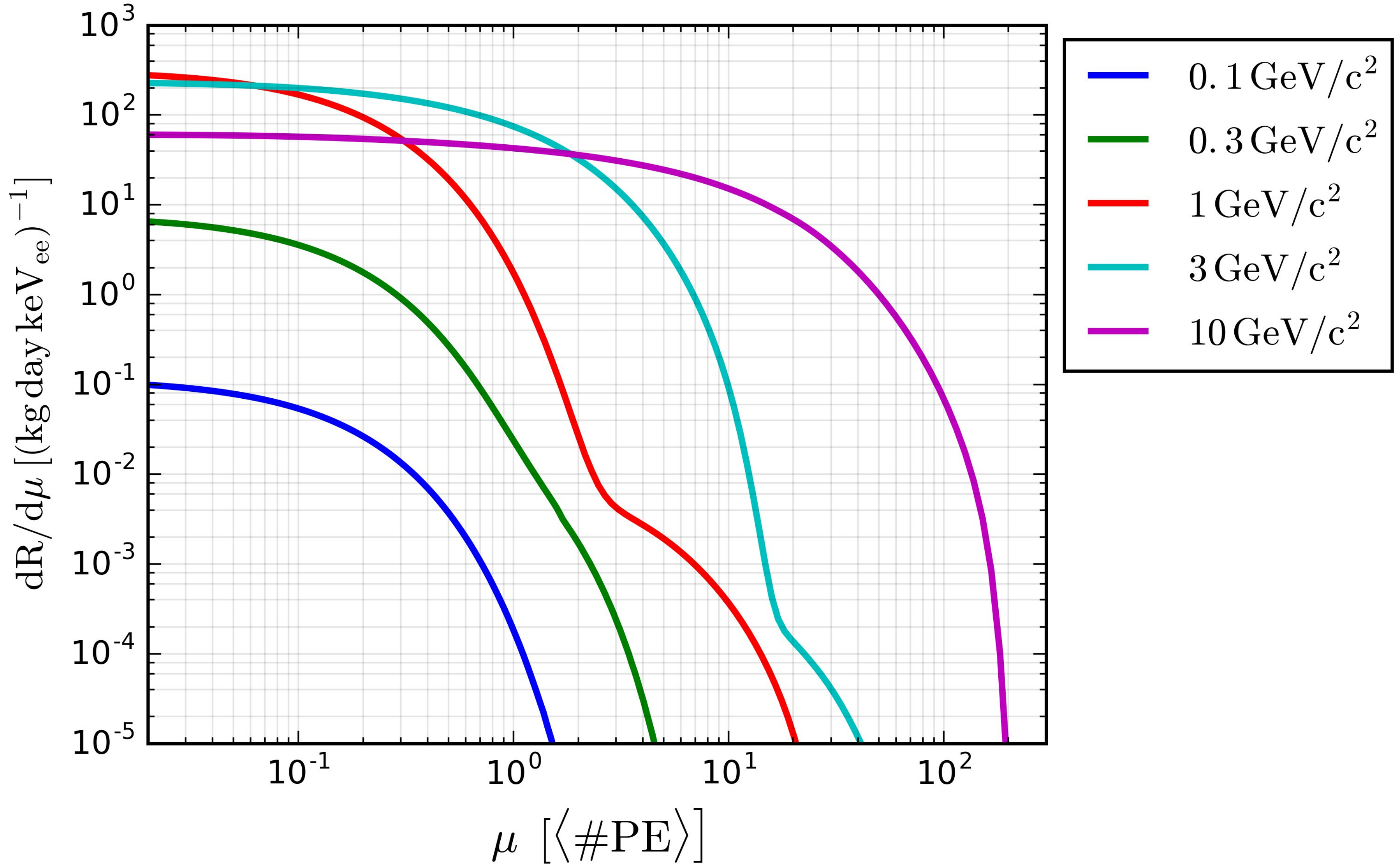
WIMP recoil spectrum

Evolution of WIMP recoil spectrum for Ne + 10% CH_4



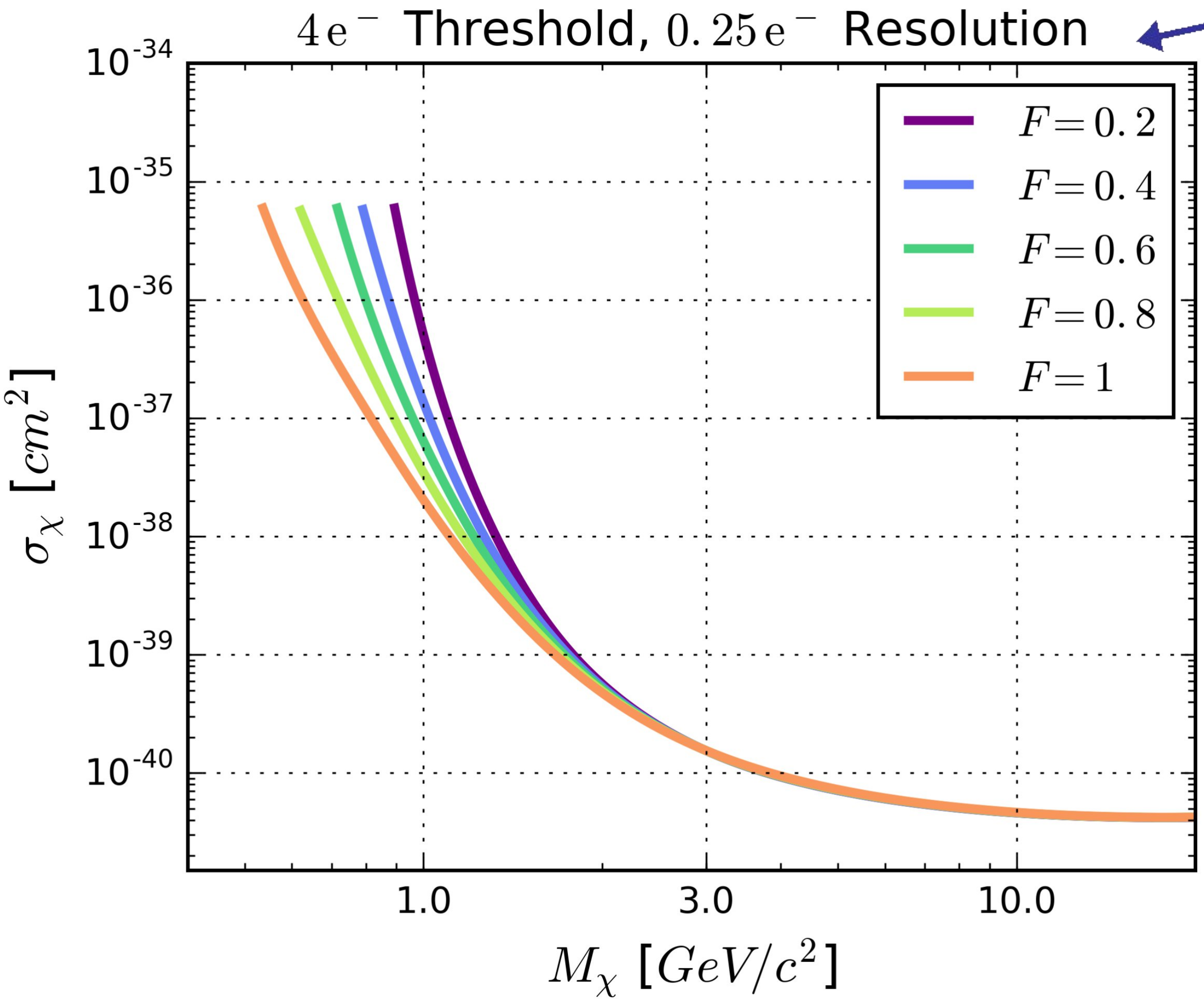
Possible structure of paper

The (proposed) main elements/sections for the sensitivity projections paper, based on similar papers from other experiments (SuperCDMS: cdms arXiv 1610.00001, LUX: arXiv 1802.06039):

1. Experimental setup
2. Sources and simulation of backgrounds
3. Detector simulation
4. Calculation of sensitivity
5. Impact of experimental parameters

Accounting for the Fano factor

We can use this tool to assess the impact on low-mass DM experiments



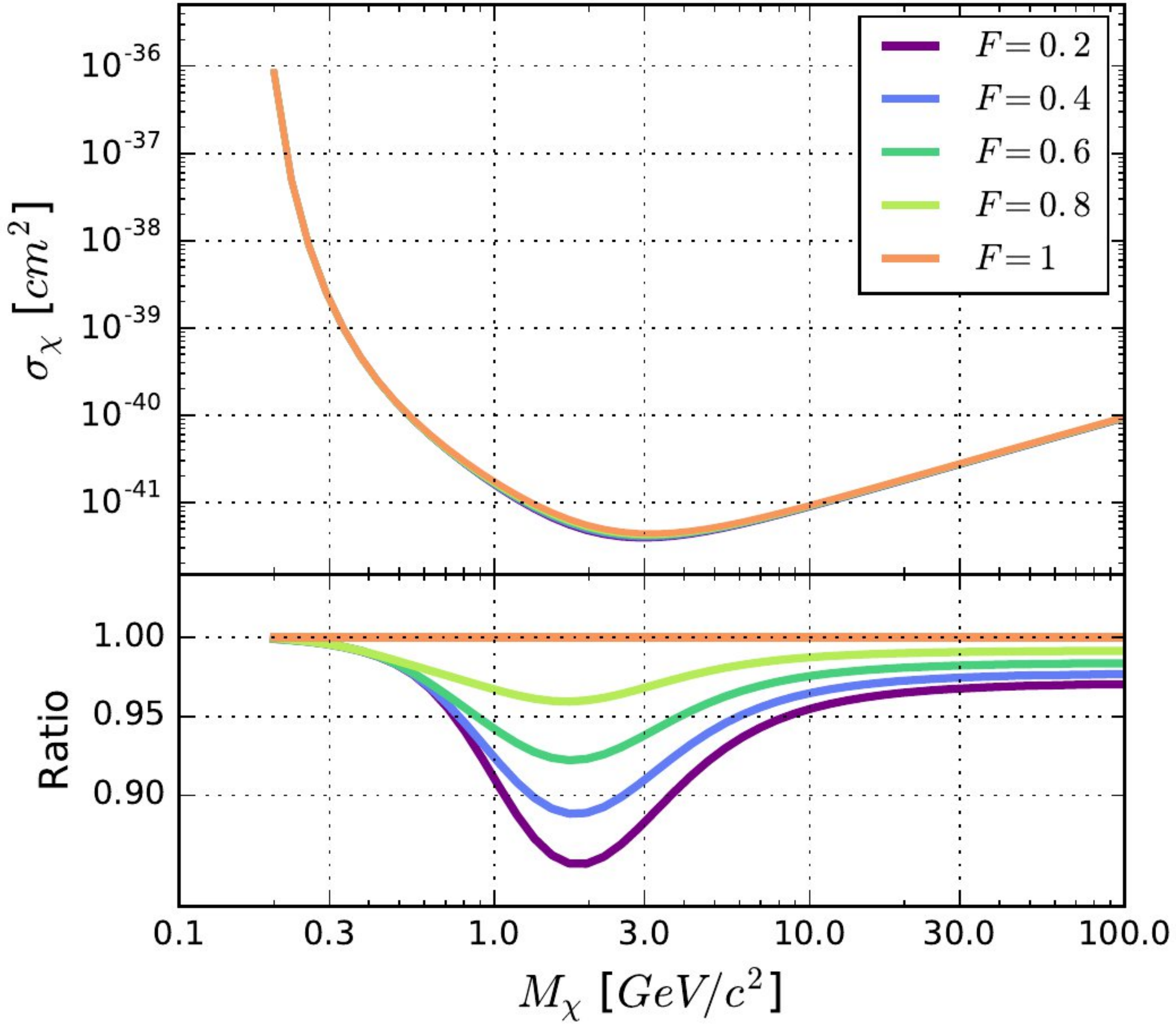
(i.e. CCD detectors like DAMIC)

F can have a big impact!

Neon experiment modelled with COM-Poisson + Gaussian resolution

Accounting for the Fano factor

We can use this tool to assess the impact on low-mass DM experiments

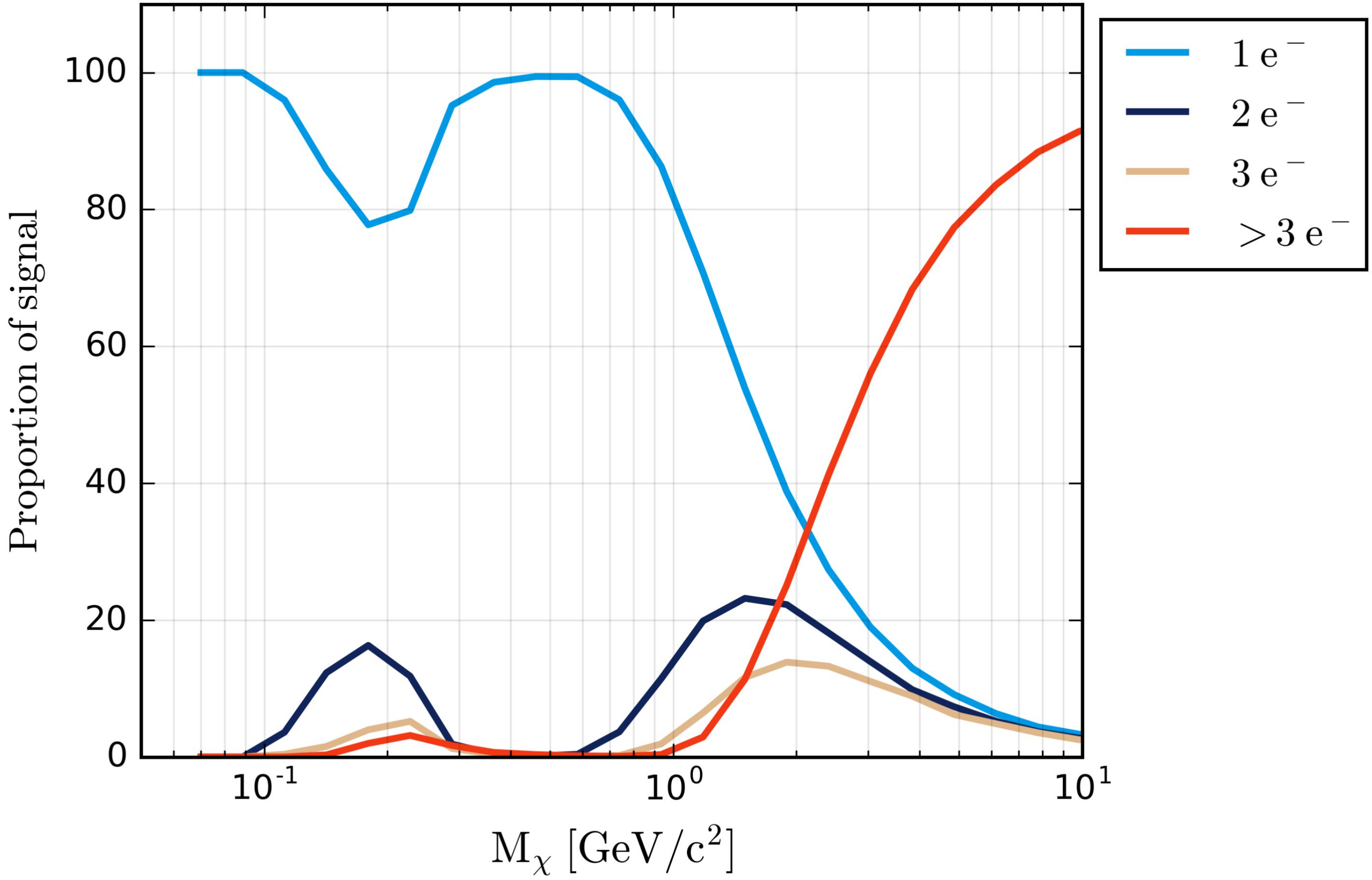


...but probably won't for NEWS-G

Neon experiment modelled with COM-Poisson + Polya, 1e$^-$ to 1 keV$_{nr}$ energy window

Possible structure of paper

Much of our sensitivity at these WIMP masses derives from 1e$^-$ events:



Therefore characterization of our single electron response is essential!