DOWN WITH HALO MODELS

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CCPP
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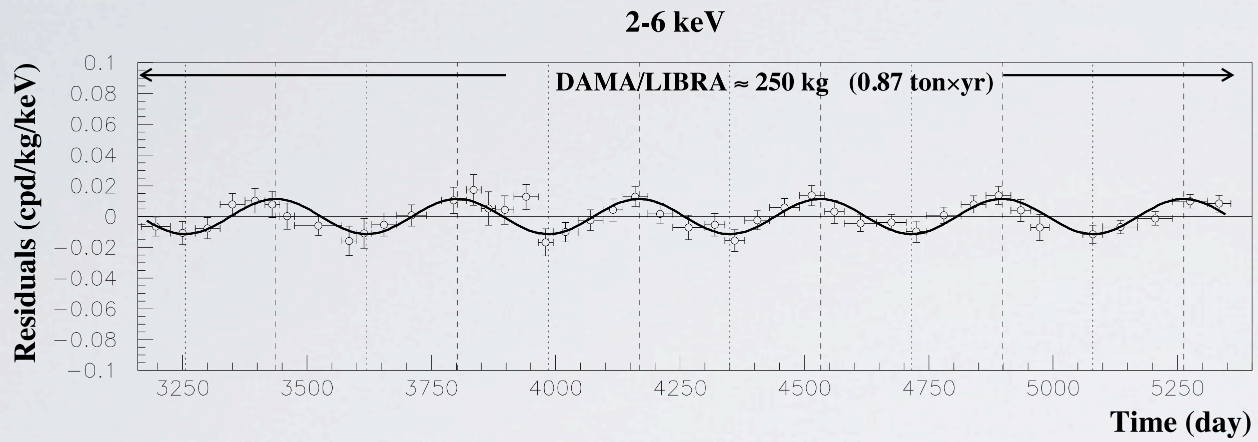
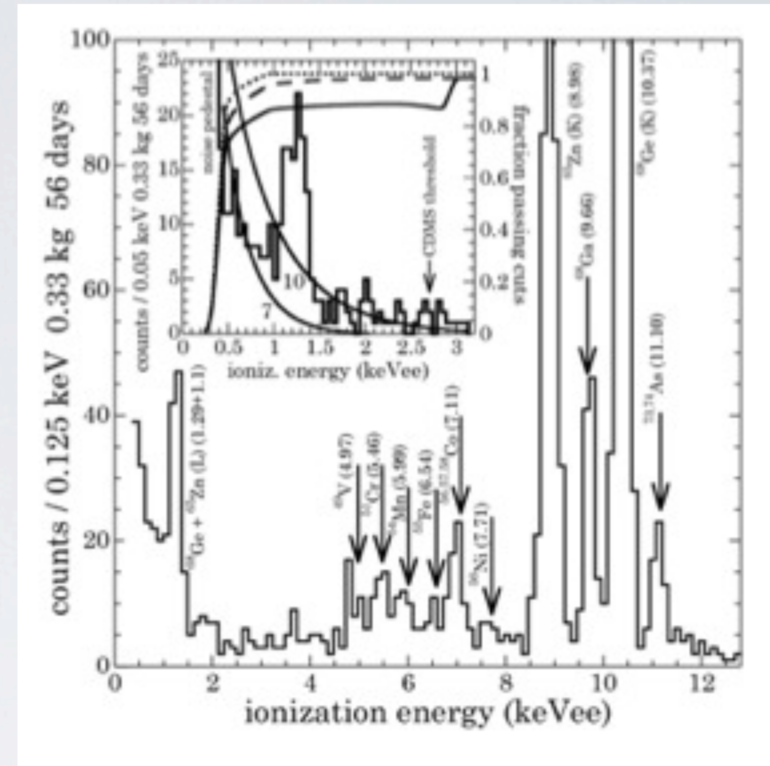
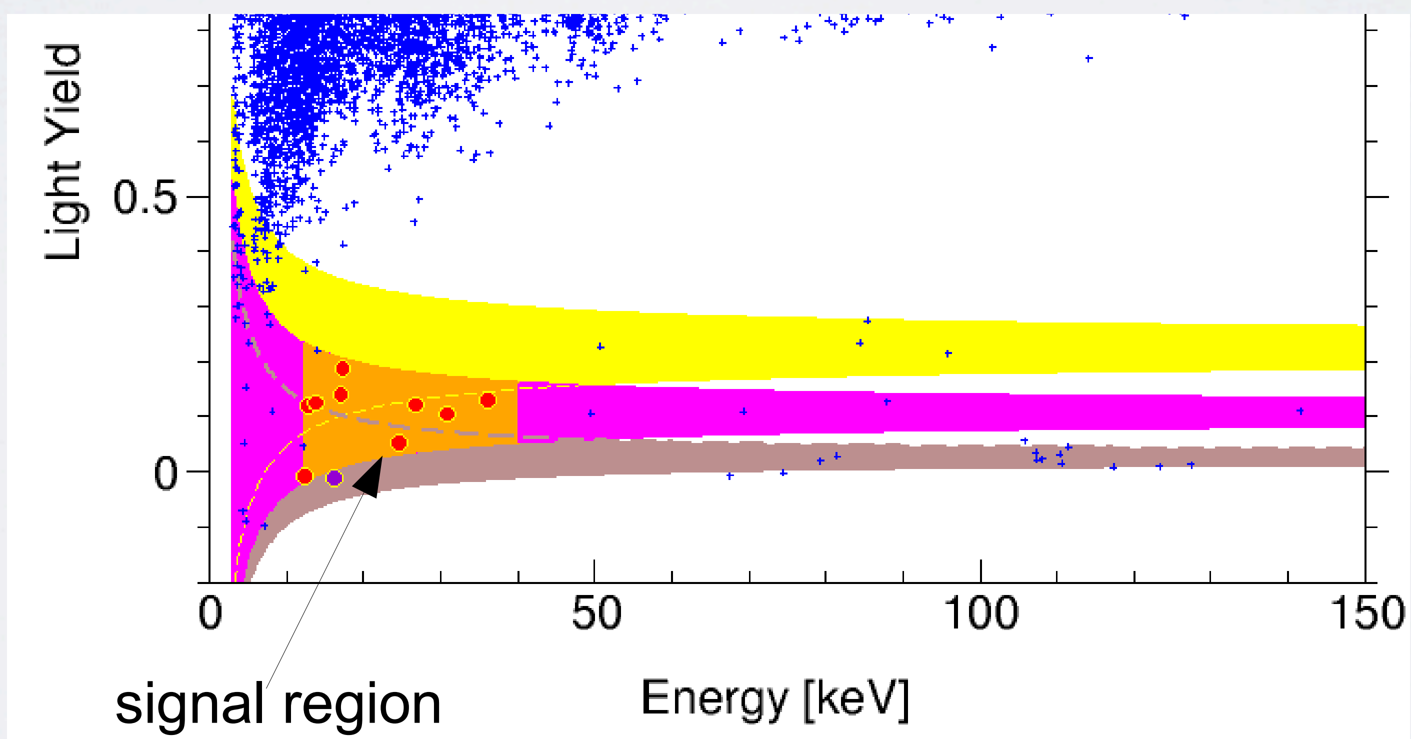
WHAT THE HECK IS GOING ON?

- A whole bunch of experiments have data
- To leading order, no one agrees with anyone
- So let's talk about that


2-6 keV
DAMA/LIBRA ≈ 250 kg (0.87 ton×yr)
Residuals (cpd/kg/keV)
Time (day)


counts / 0.125 keV 0.33 kg 56 days
ionization energy (keVee)
ioniz. energy (keVee)
fraction passing cuts


Light Yield
Energy [keV]
signal region

LIGHT WIMPS?!?!?!

- DAMA *modulation* through Na

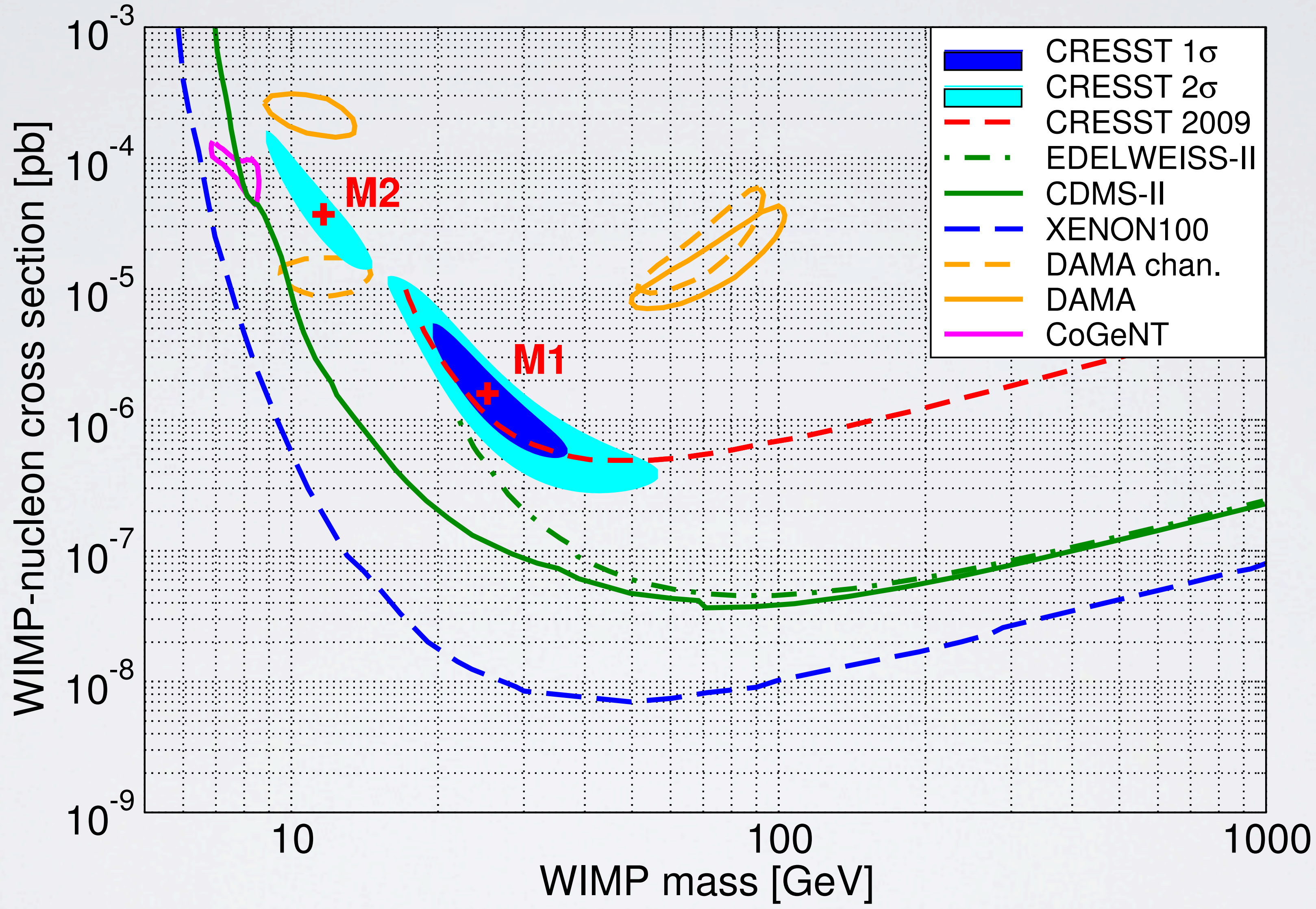
- CoGeNT low energy scattering on Ge

Different targets
Different **type** of signal
Different level of **S/B**

- CRESST scattering through O (and Ca) *above energy dependent backgrounds*

Important to understand the experiments in as *model independent* manner as possible

IS THIS CONSISTENT?



NB: This is not a metric space!

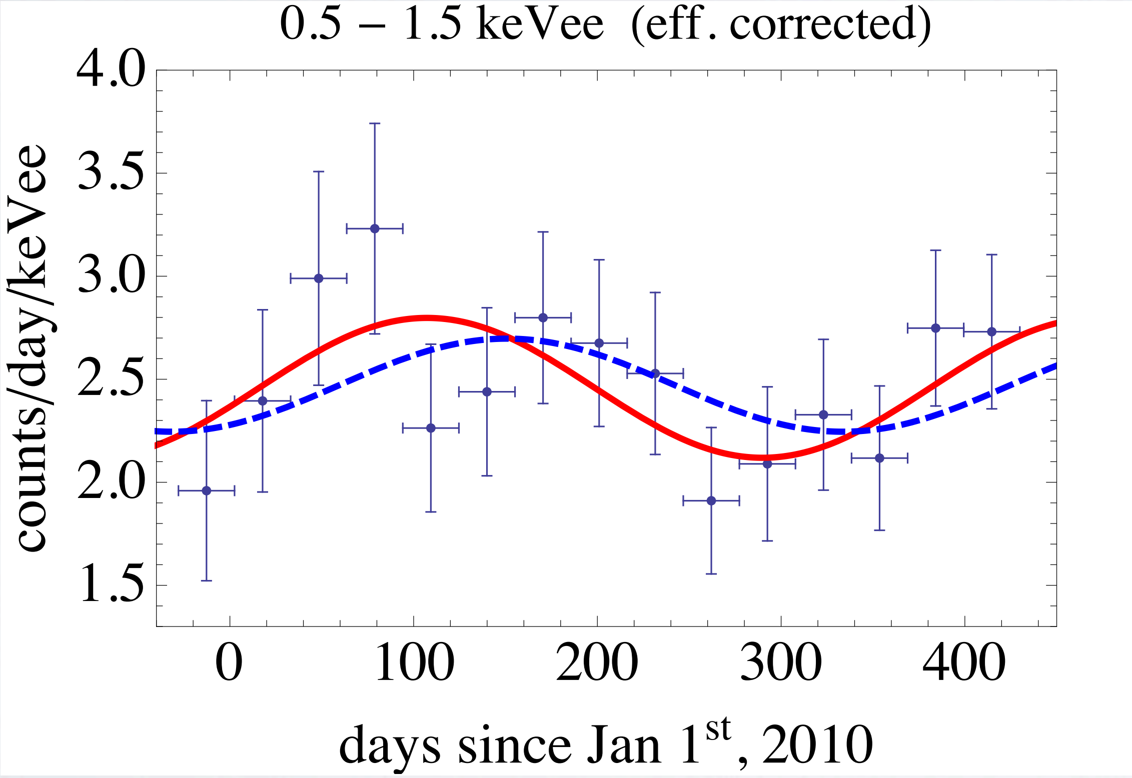
TWO QUESTIONS

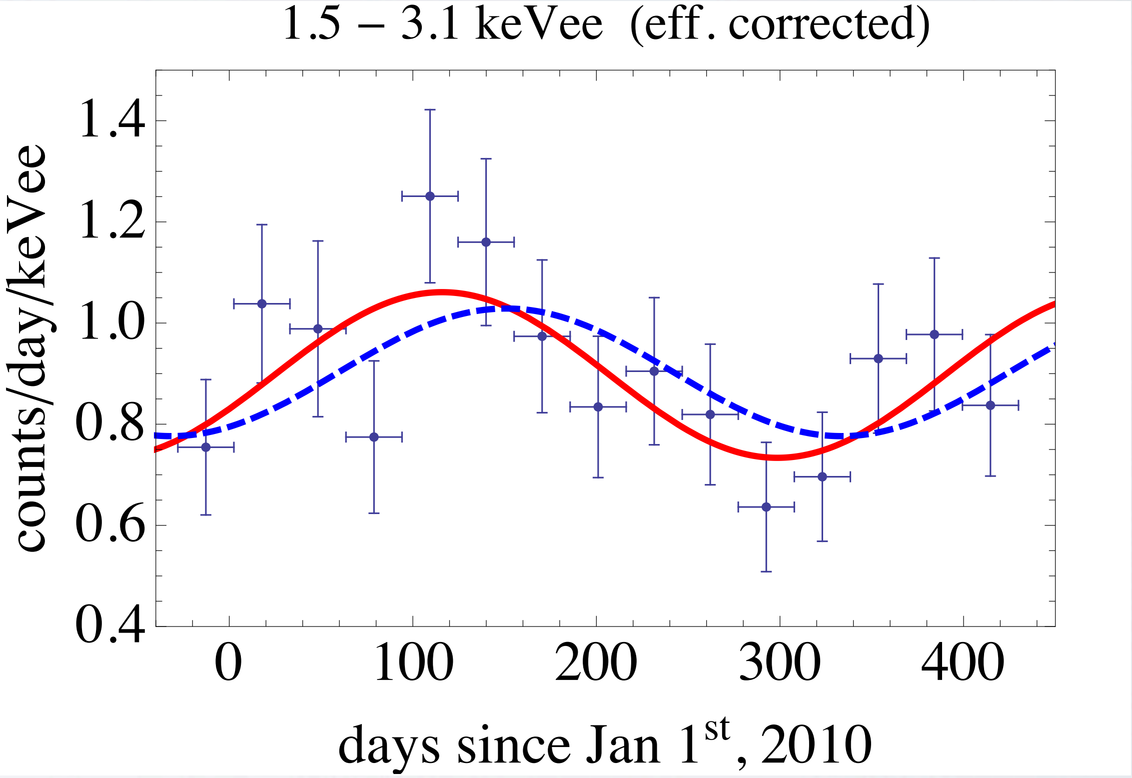
- Are there signs of WIMPs in CoGeNT (i.e., modulation)?
- Can you relate experiments without assuming Maxwellian distribution?

LETS TALK MODULATION

SIMPLE QUESTION

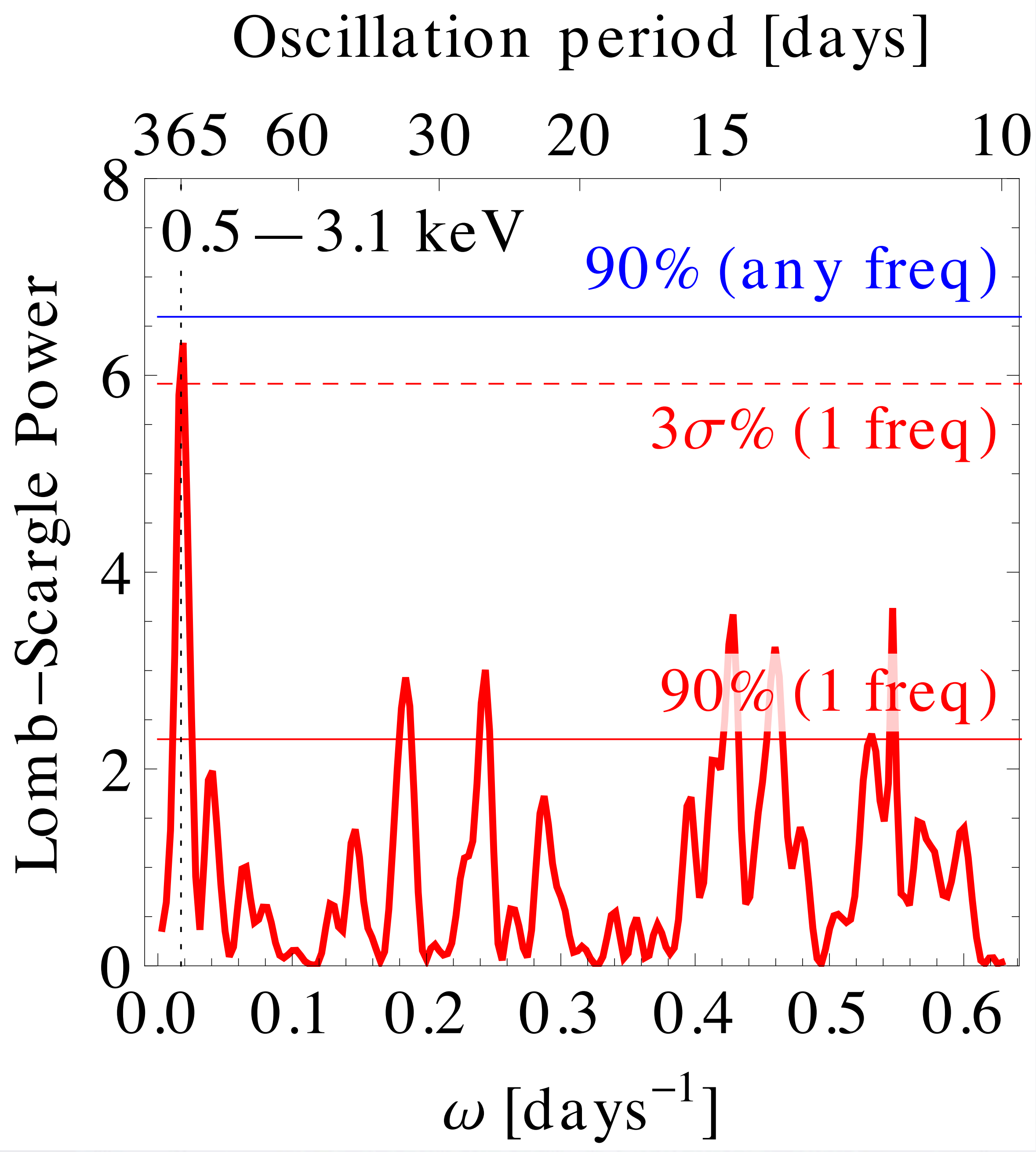
- If there's modulation at DAMA, is there modulation at CoGeNT?





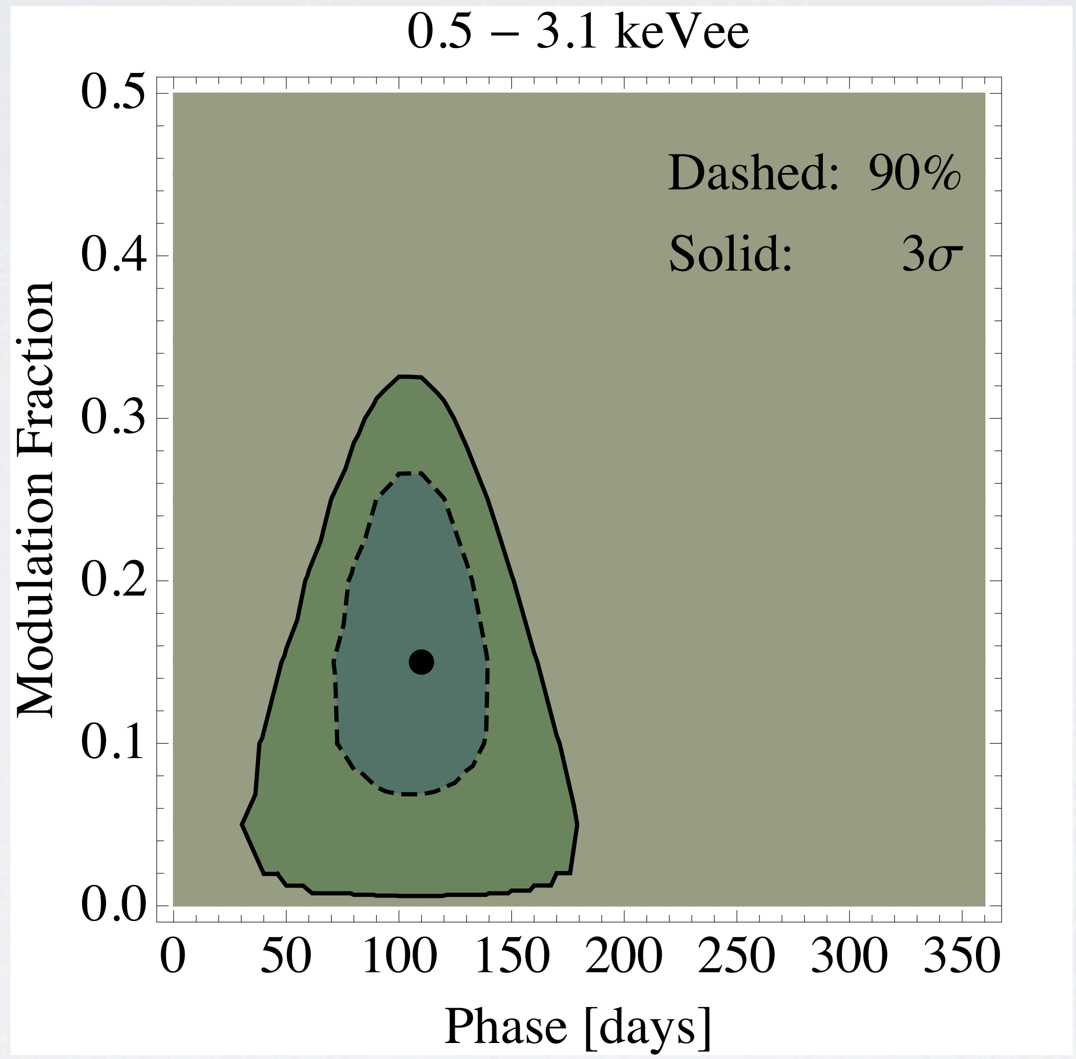
SIMPLE QUESTION

- Is there modulation in any other frequency?



SIMPLE QUESTION

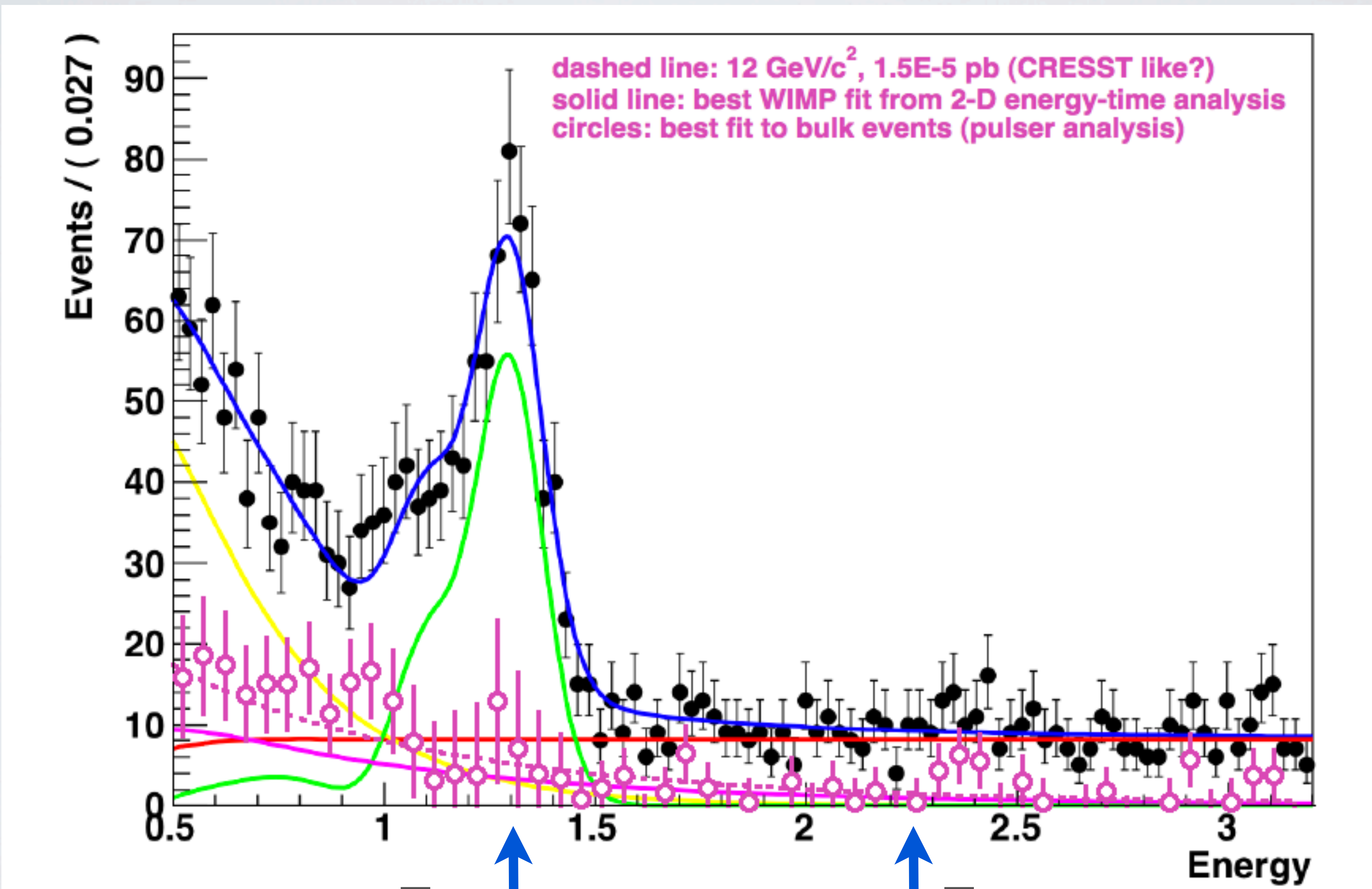
- What is the modulated fraction and phase?



Seemingly not at 152 days... *large* modulated fraction

SIMPLE QUESTION

- Where (in energy) is the modulation?

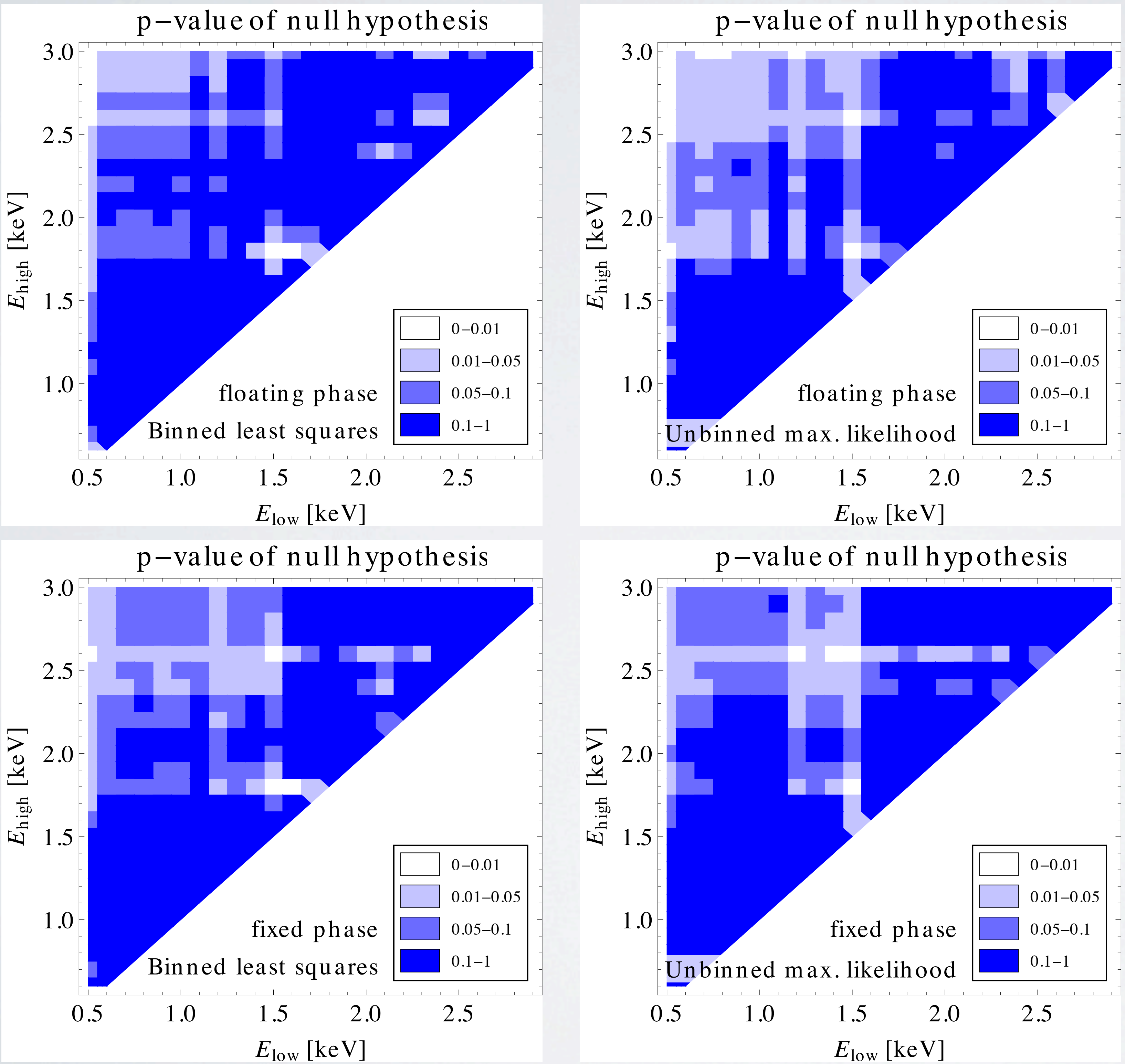


E_{low} ⟷ E_{high}

What is the modulation in this range?

SIMPLE QUESTION

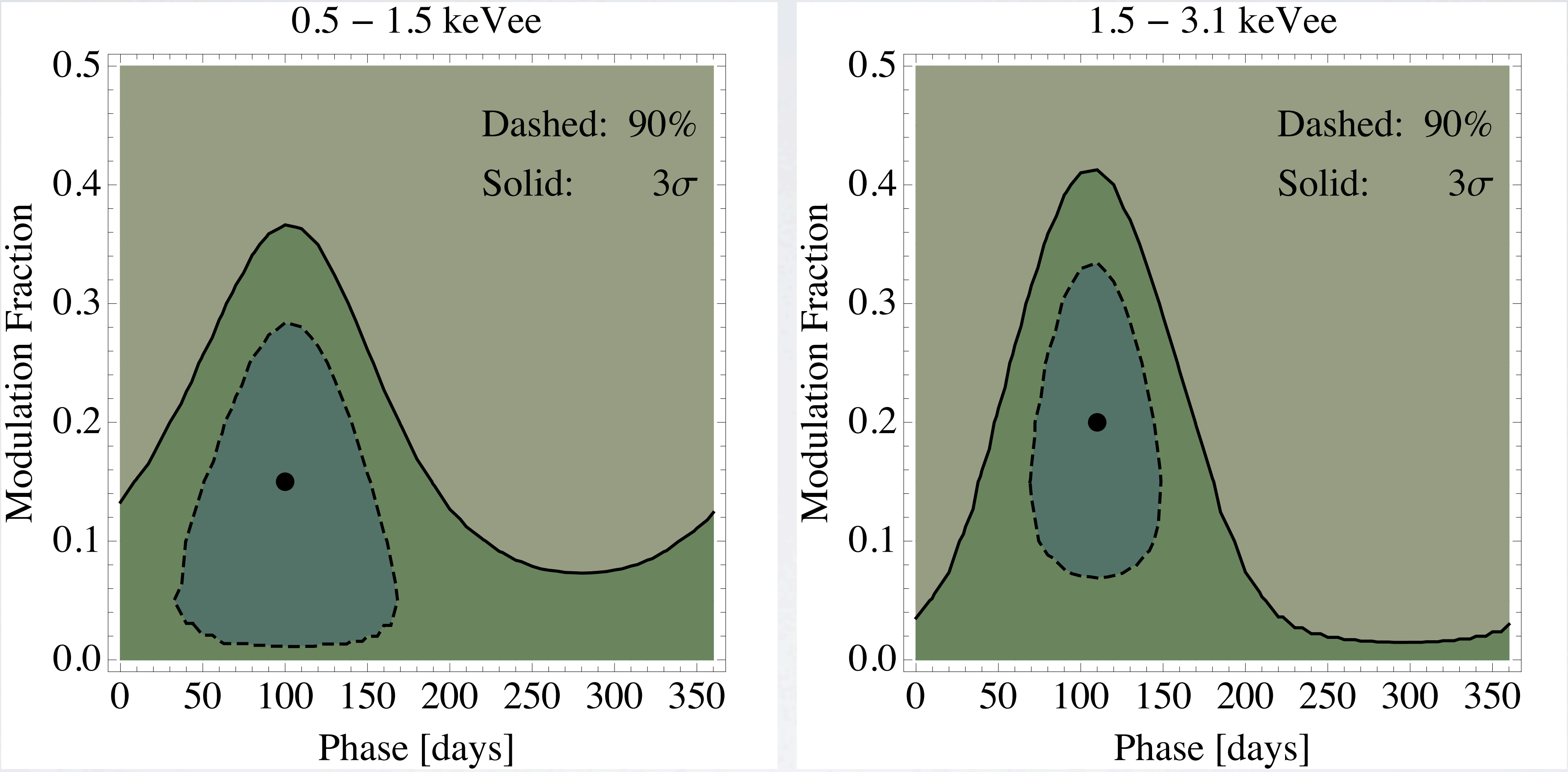
- Where (in energy) is the modulation?



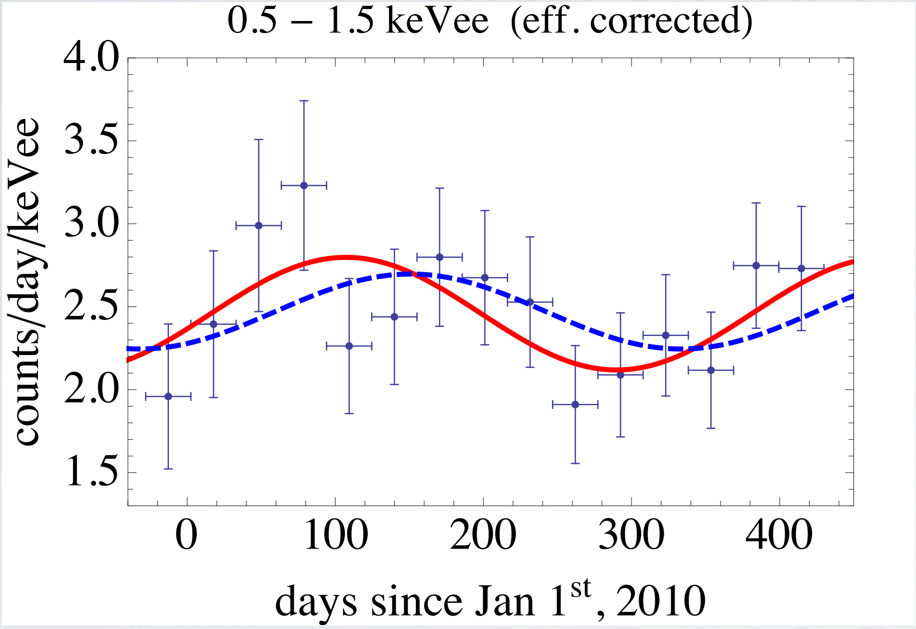
Lots of modulation at high energy?

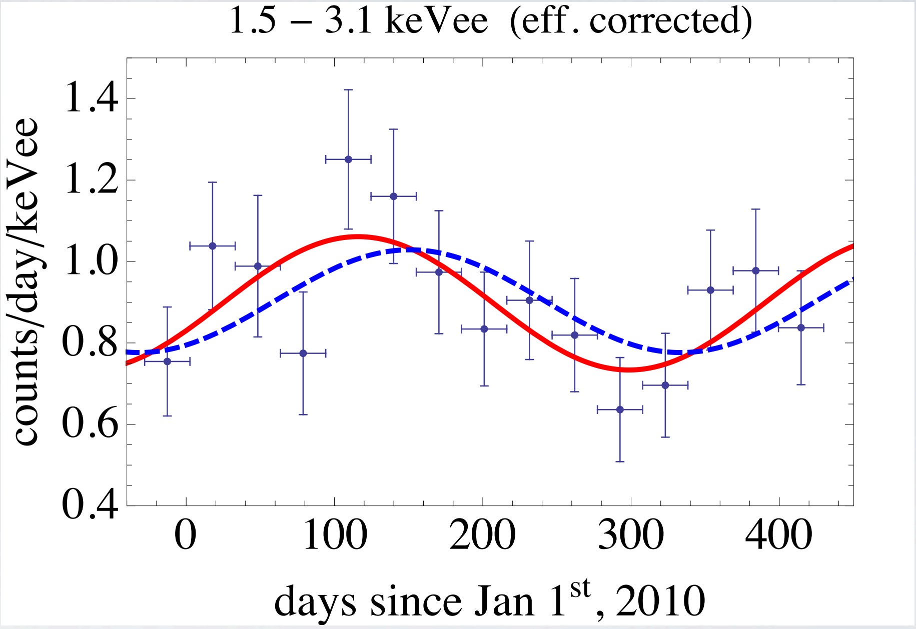
SIMPLE QUESTION

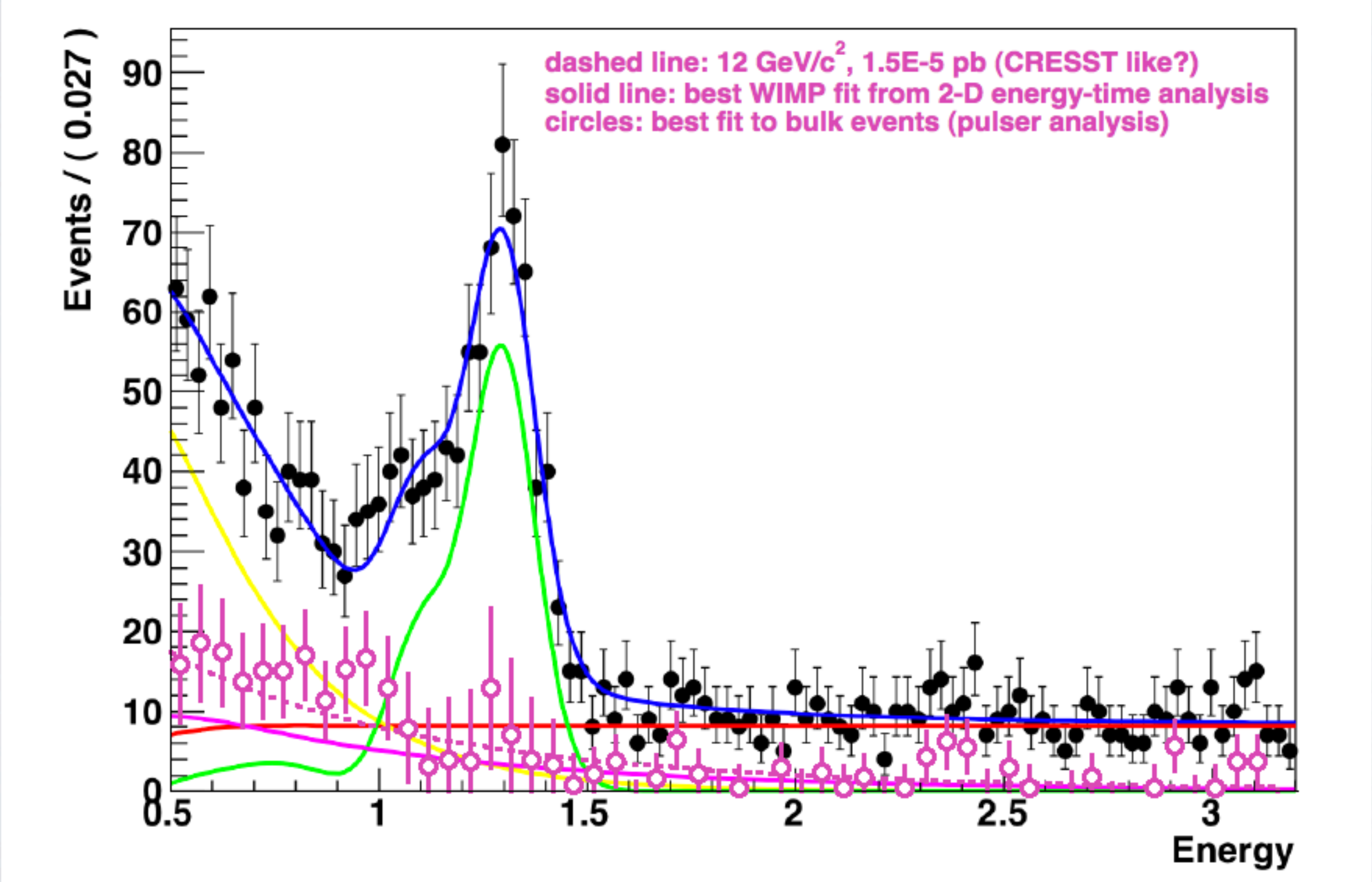
- Where (in energy) is the modulation?



Modulation is statistically more significant at high energies (low energies depend on lowest bin)







I count about 50 (or maybe 100?) events up here

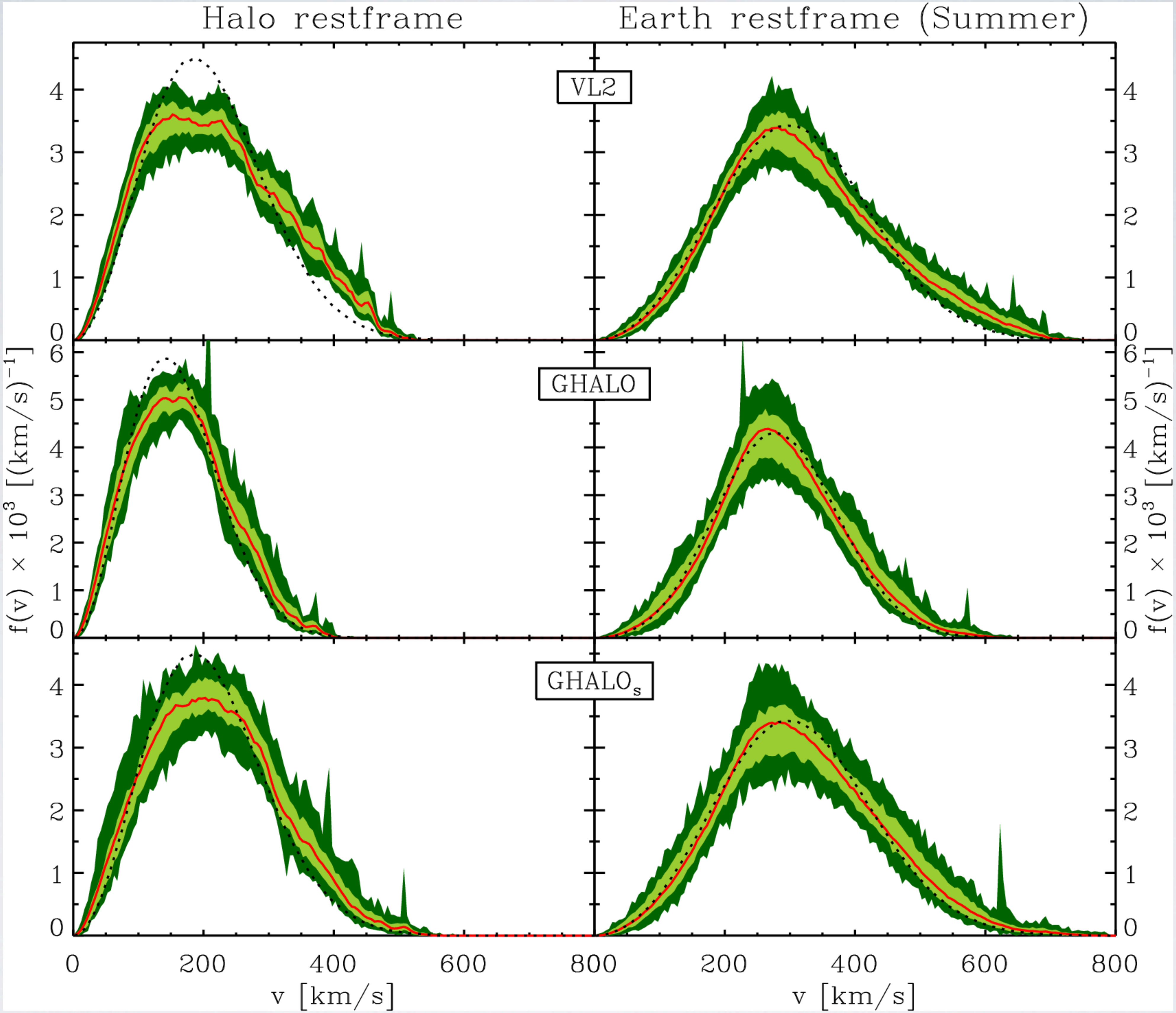
If efficiencies are O(1) => 0.37 (0.74) cpd/kg vs 0.78

so is it modulating?

LIGHT WIMP SUMMARY

- Nothing overlaps
- Modulation is way higher than expected
- Simple extrapolation leads to conflicts with null results
- What to do?

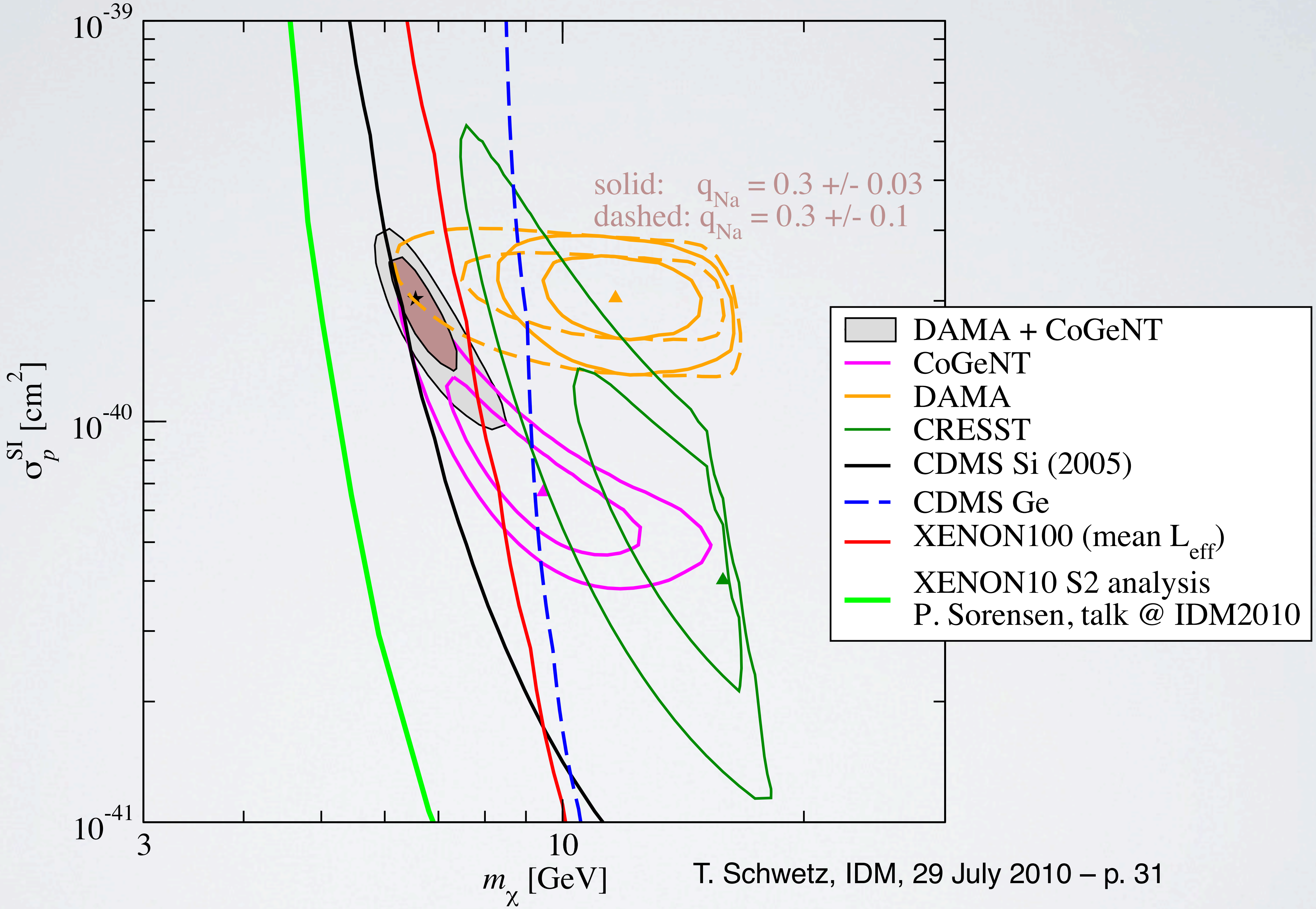

HALO
WARS
The model builder's last refuge...



Kuhlen, et al

MB generally good near the peak, generally not near the tail

WHAT HAPPENS TO THIS PLOT?



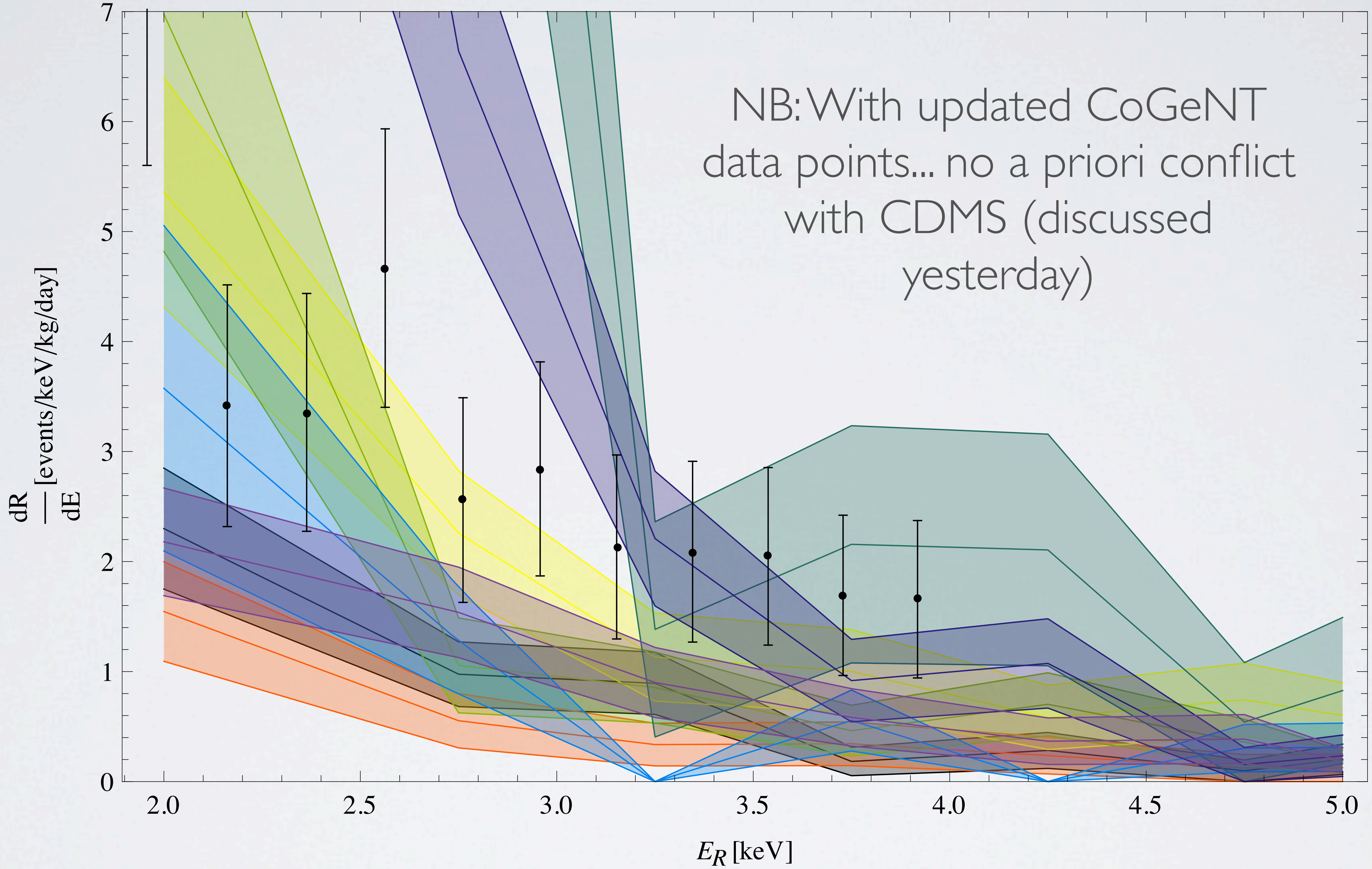
T. Schwetz, IDM, 29 July 2010 – p. 31

THE GOAL

- What can we say about direct detection experiments without making any appeal to halo models?

- Find Dark Matter
- ~~Determine DM mass~~
- ~~Determine DM interaction strength~~

COGENT=>CDMS



Can you do this with other experiments?

TWO KEY POINTS

$$\frac{dR}{dE_R} = \frac{N_T M_T \rho}{2 m_\chi \mu^2} \sigma(E_R)\, g(v_{min})$$

$$g(v_{min}) = \int_{v_{min}}^{\infty} d^3v\, \frac{f(\mathbf{v},t)}{v}$$

$$\sigma_{SI}(E_R) \;=\; \sigma_p \frac{\mu^2}{\mu_{n\chi}^2} \frac{\left(f_p\, Z + f_n\, (A-Z)\right)^2}{f_p^2} F^2(E_R)$$

1) all the energy dependence is in two functions

$$v_{min} = \sqrt{\frac{M_T E_R}{2\mu^2}}$$

2) there is a 1-1 mapping between velocity and energy

THE IDEA: PART 1

- Suppose you want to compare two experiments, 1 and 2

$$[E^1_{low}, E^1_{high}] \Rightarrow [v^{1,low}_{min}, v^{1,high}_{min}]$$

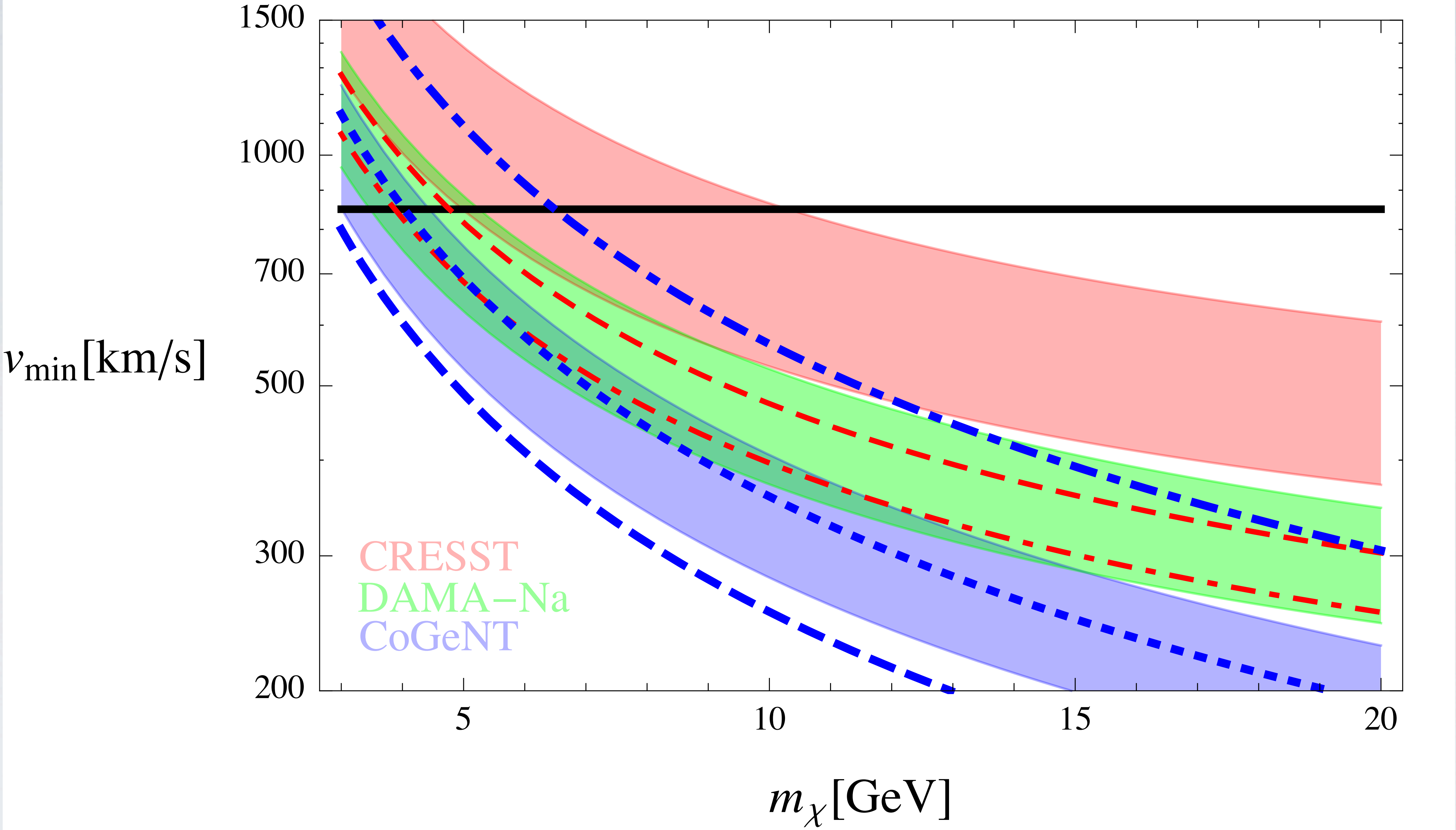
map the energy range studied in experiment 1 to a velocity space range

map velocity space range back to energy space for experiment 2

$$[v^{1,low}_{min}, v^{1,high}_{min}] \Rightarrow [E^2_{low}, E^2_{high}]$$

we now have an energy range where the experiments are studying the *same* particles

$$[E^1_{low}, E^1_{high}] \Leftrightarrow [E^2_{low}, E^2_{high}]$$



Approx. range	O	Na	Si	Ar	Ge	Xe
CoGeNT (Ge): 2 - 4	4.3 - 8.6	3.9 - 7.8	3.6 - 7.2	3.0 - 6.0	2 - 4	1.3 - 2.5
DAMA (Na): 6 - 13	6.6 - 14	6 - 13	5.5 - 12	4.6 - 10	3.1 - 6.7	1.9 - 4.2
CRESST (O): 15 - 40	15 - 40	14 - 36	12 - 33	10 - 28	6.9 - 19	4.3 - 12

TABLE I: Conversion of energy ranges (all in keV) between various experiments/targets for a 10 GeV DM particle, using the expression in (7).

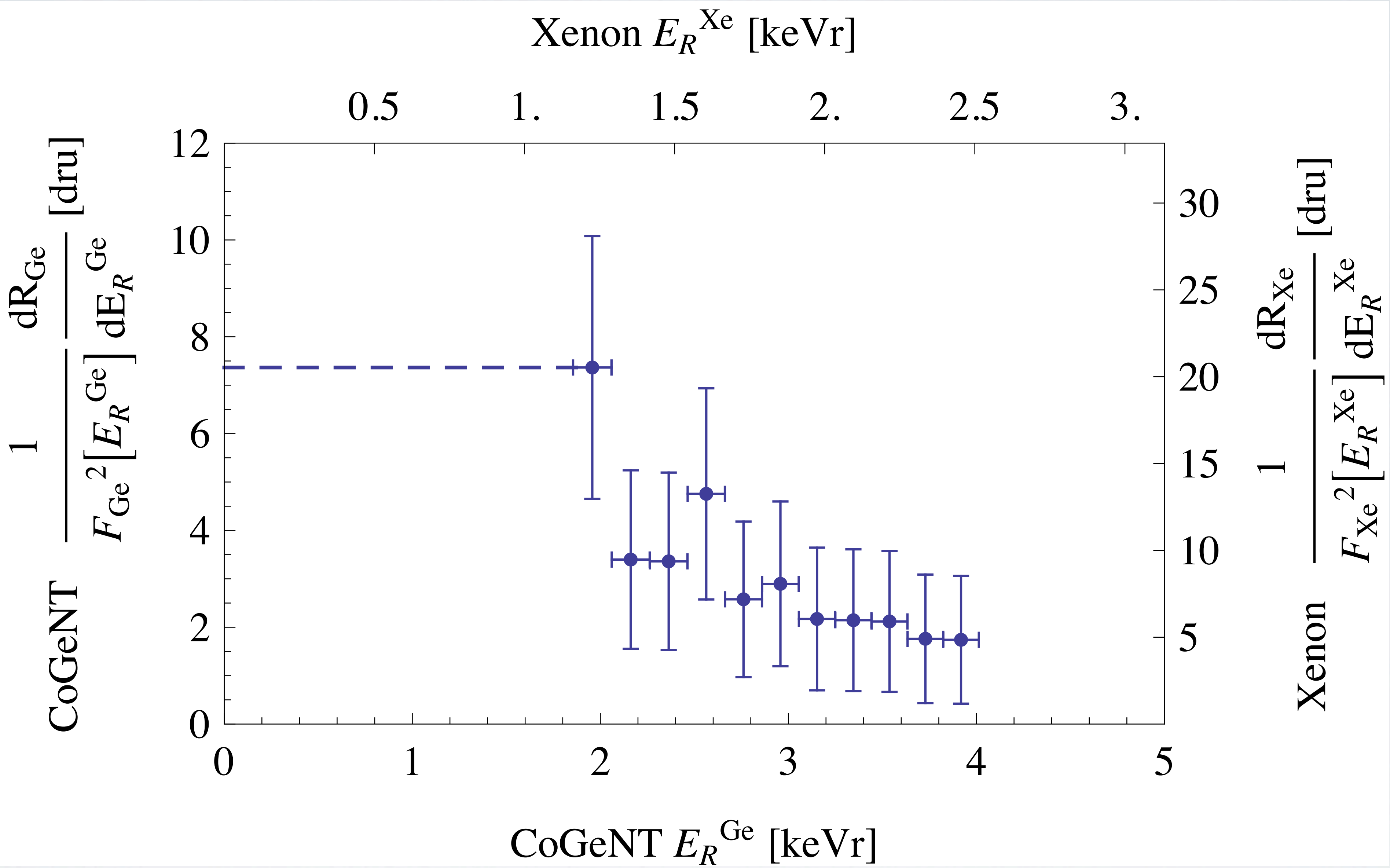
THE IDEA: PART 2

Invert:

$$\frac{dR}{dE_R} = \frac{N_T M_T \rho}{2 m_\chi \mu^2} \sigma(E_R)\, g(v_{min}) \longrightarrow g(v) = \frac{2 m_\chi \mu^2}{N_T M_T \rho \sigma(E_R)} \frac{dR_1}{dE_1}$$

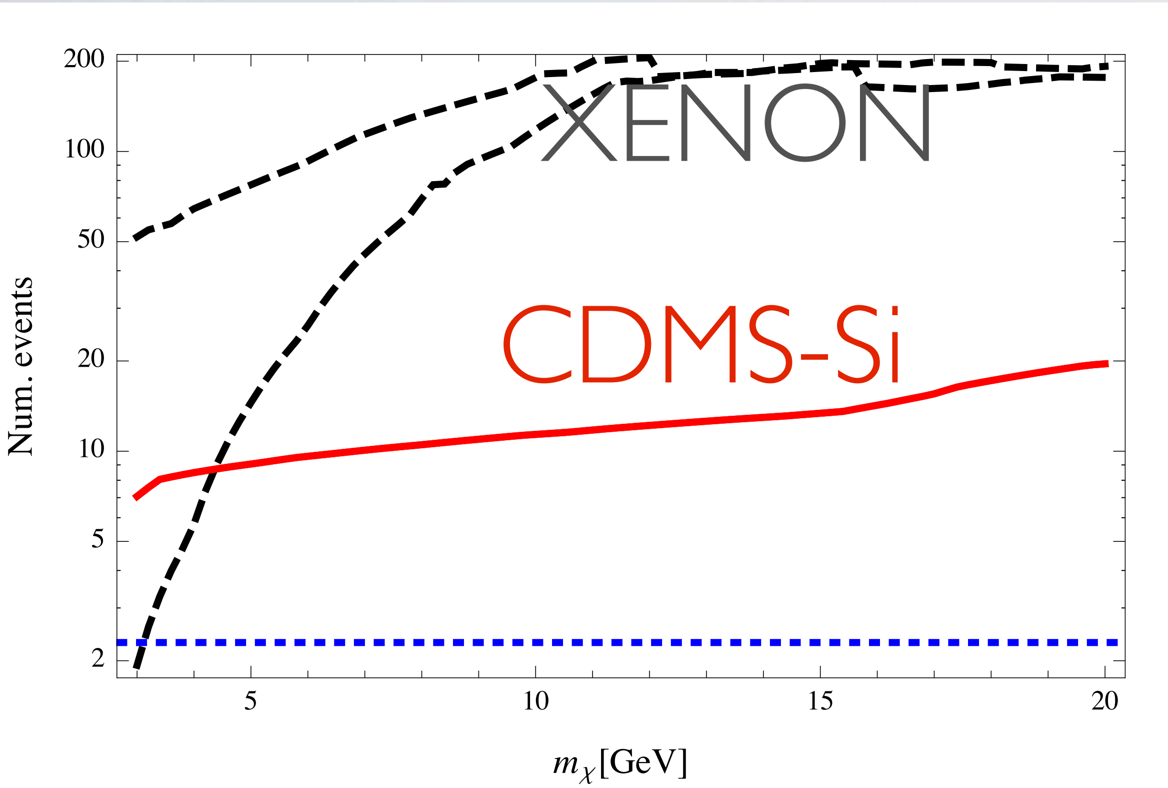
$$\frac{dR_2}{dE_R}(E_2) = \frac{C_T^{(2)}}{C_T^{(1)}} \frac{F_2^2(E_2)}{F_1^2\left(\frac{\mu_1^2 M_T^{(2)}}{\mu_2^2 M_T^{(1)}} E_2\right)} \frac{dR_1}{dE_R}\left(\frac{\mu_1^2\, M_T^{(2)}}{\mu_2^2\, M_T^{(1)}} E_2\right)$$

A direct prediction of the rate at experiment 2 from experiment 1



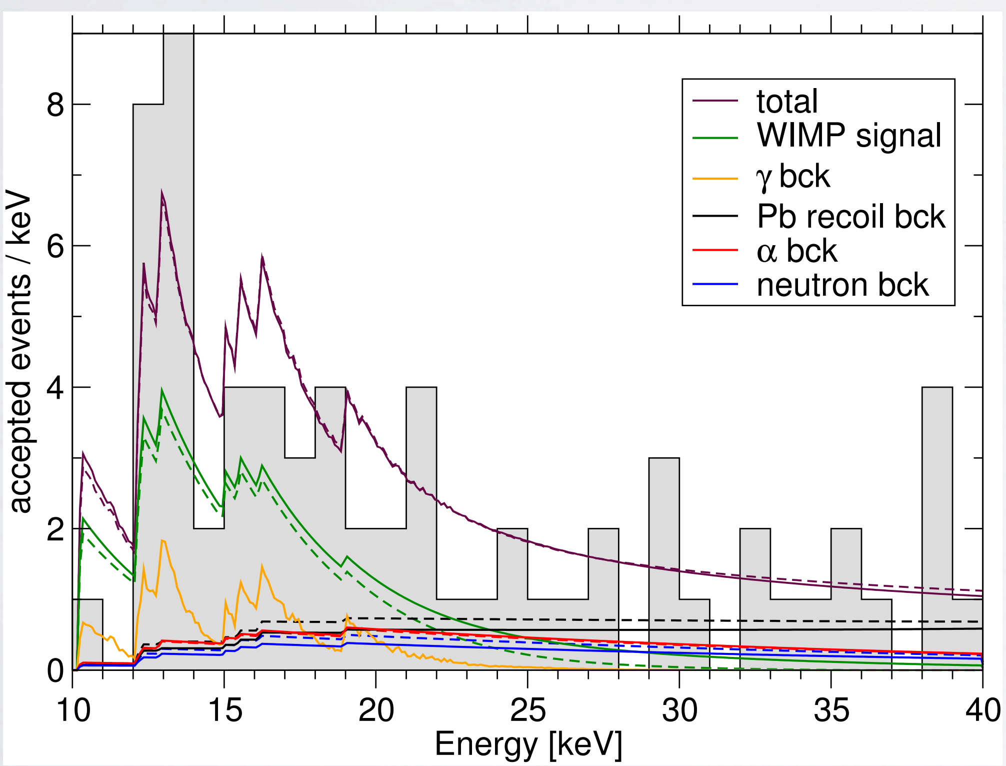
When new data finalize, can reapply, but approach is same

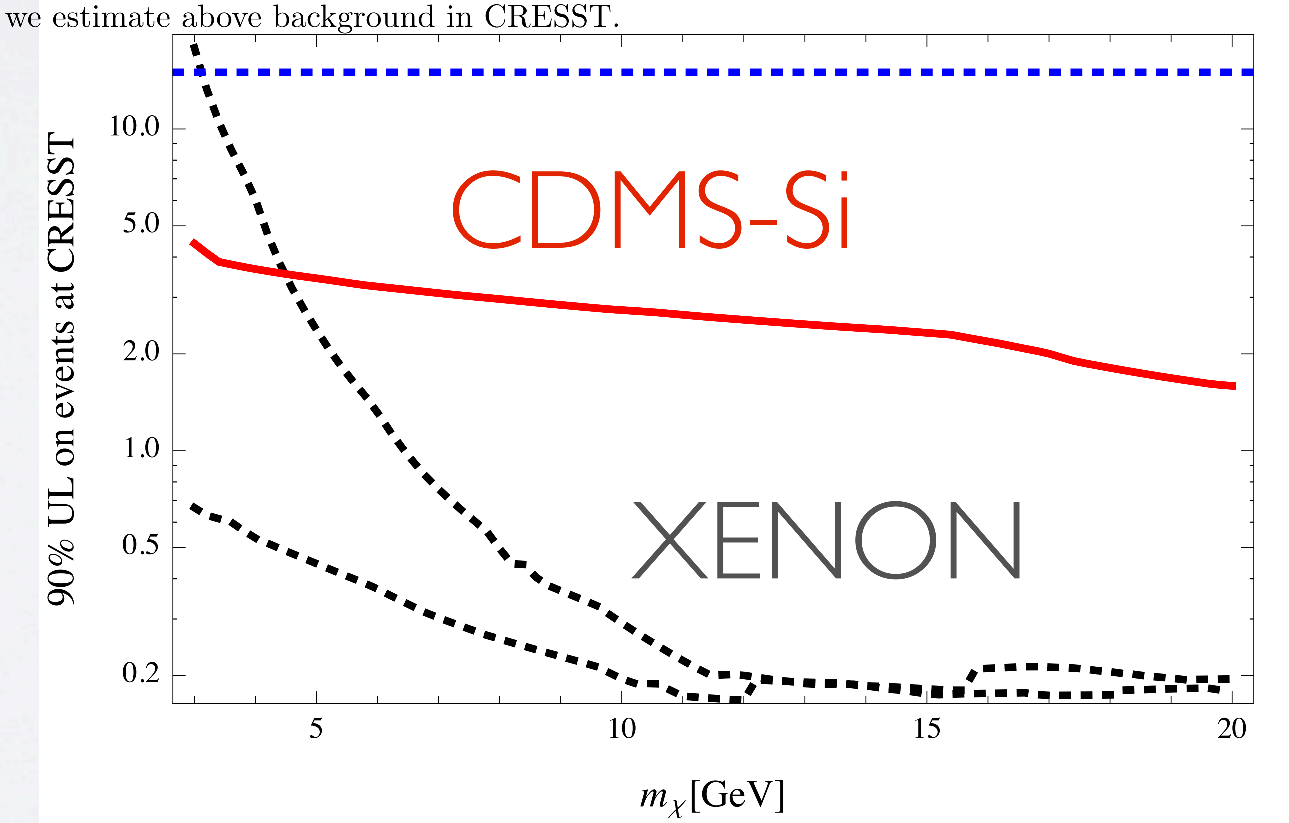
(plots from preliminary data)



module	E_{acc}^{min} [keV]	acc. events
Ch05	12.3	11
Ch20	12.9	6
Ch29	12.1	17
Ch33	15.0	6
Ch43	15.5	9
Ch45	16.2	4
Ch47	19.0	5
Ch51	10.2	9
total	-	**67**

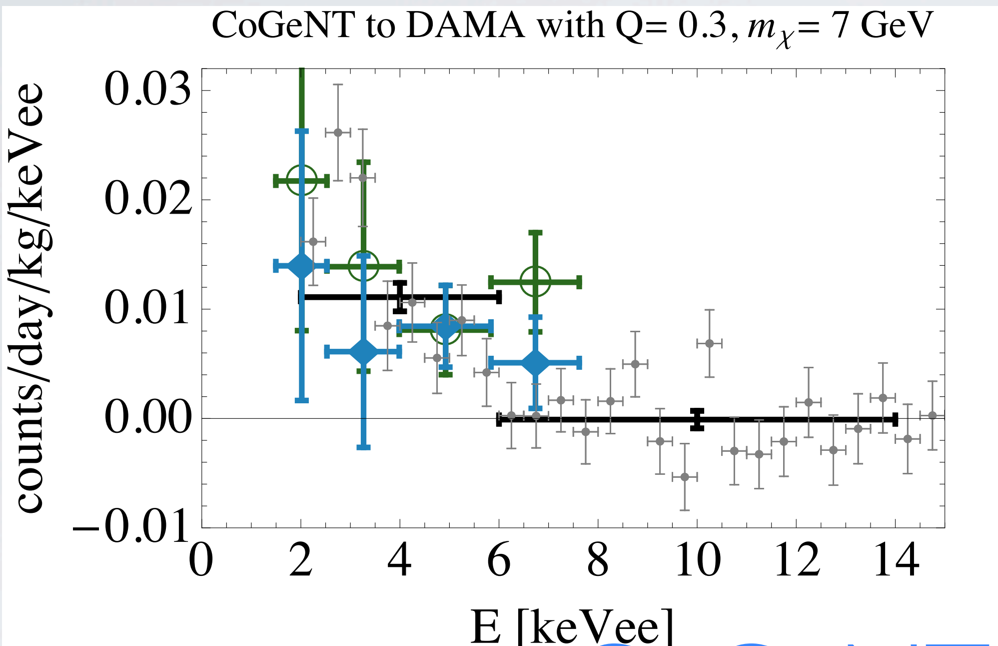
FIG. 5: LH plot: the CRESST prediction for the total number of events at CDMS-Si (solid red) and XENON10, for $\mathcal{L}_{eff}^{MIN}$ (dashed black) and $\mathcal{L}_{eff}^{MED}$ (dotted black), the dotted (blue) line is the 90% C.L. upper limit on the number of events allowed by CDMS-Si. RH plot: the 90% C.L. upper limit on the number of events at CRESST as predicted by CDMS-Si (solid red) and XENON10, again for $\mathcal{L}_{eff}^{MIN}$ (dashed black) and $\mathcal{L}_{eff}^{MED}$ (dotted black), the dotted (blue) line is the number of events we estimate above background in CRESST.

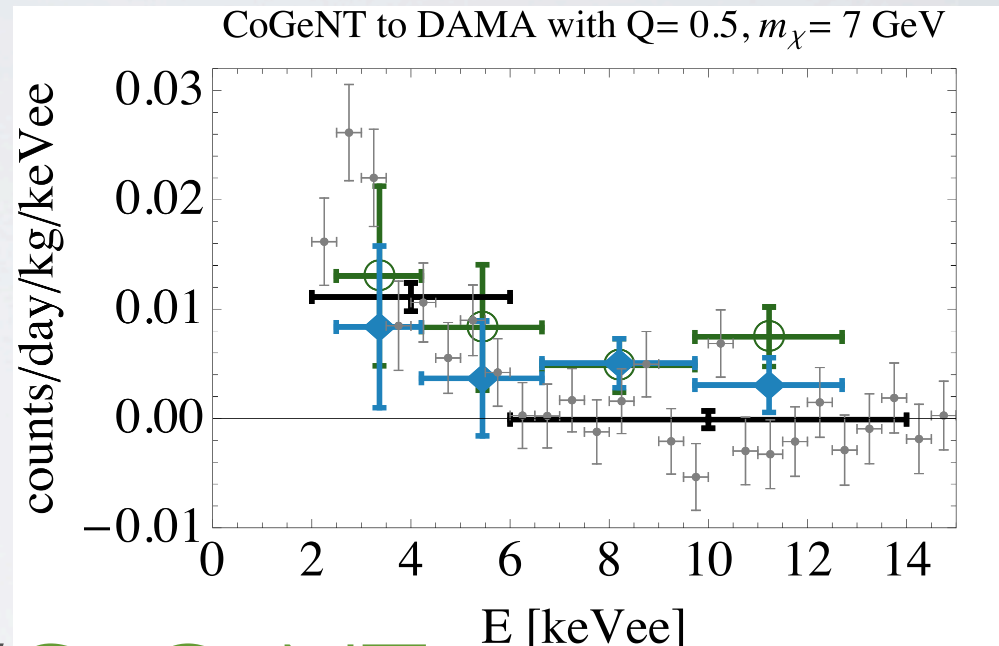




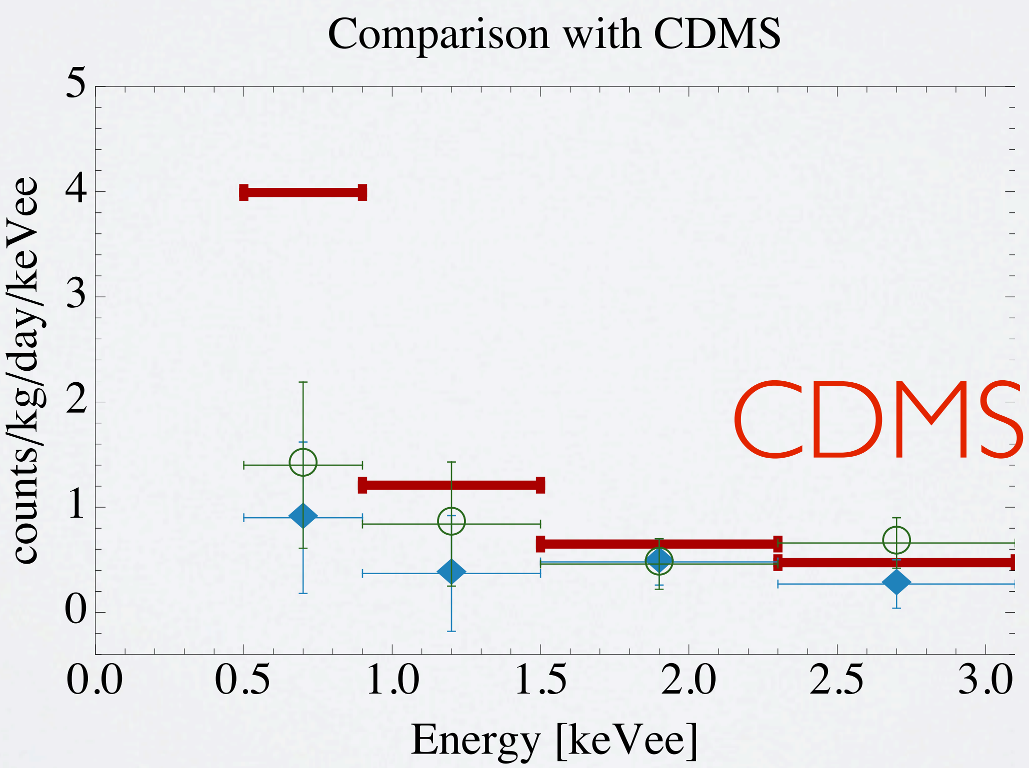
MODULATION

DAMA/DAMA





CoGeNT/CoGeNT



CoGeNT “exponential” signal

Bin	CoGeNT	Ge	Na (Q=0.3)	Si	O	Xe
1	[0.5,0.9] 0.90 ± 0.72	[2.3,3.8] 0.23 ± 0.18	[1.5,2.5] 0.078 ± 0.062	[4.5,7.6] 0.035 ± 0.028	[5.8,9.9] 0.011 ± 0.009	[1.4,2.3] 0.72 ± 0.58
2	[0.9,1.5] 0.37 ± 0.55	[3.8,6.1] 0.1 ± 0.149	[2.5,4.0] 0.035 ± 0.052	[7.6,11.9] 0.015 ± 0.023	[9.9,15.6] 0.005 ± 0.008	[2.3,3.7] 0.31 ± 0.46
3	[1.5,2.3] 0.48 ± 0.22	[6.1,8.9] 0.136 ± 0.063	[4.0,5.8] 0.049 ± 0.022	[11.9,17.5] 0.021 ± 0.01	[15.6,22.8] 0.007 ± 0.003	[3.7,5.4] 0.41 ± 0.19
4	[2.3,3.1] 0.27 ± 0.23	[8.9,11.6] 0.08 ± 0.068	[5.8,7.6] 0.029 ± 0.025	[17.5,22.8] 0.013 ± 0.011	[22.8,29.8] 0.004 ± 0.004	[5.4,7] 0.23 ± 0.2

CoGeNT modulation/CRESST signal

For XENON100 need full efficiency Green’s functions to calculate limits

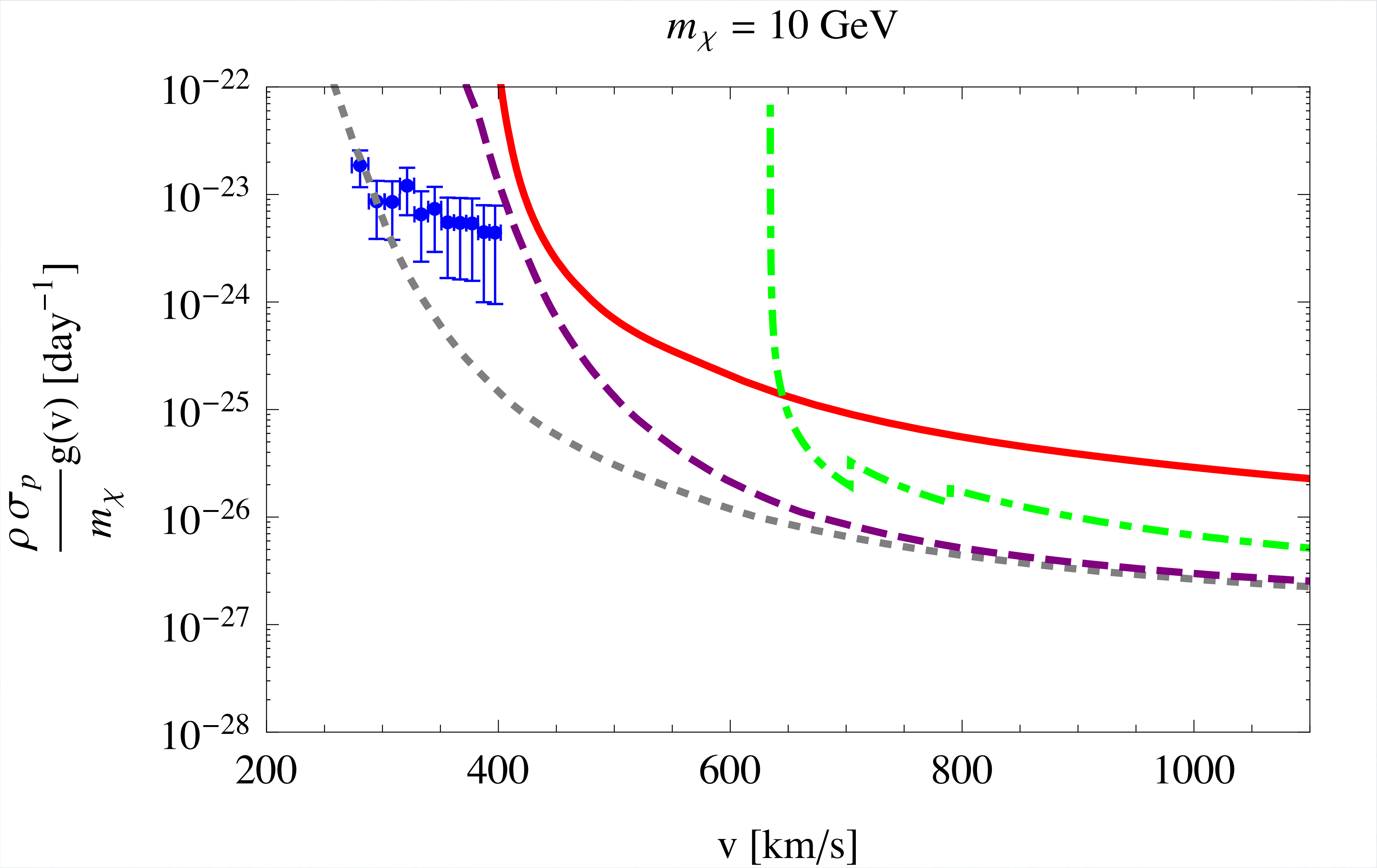
CONSTRAINTS?

What if your experiment

a) doesn’t probe the same vmin space?
b) doesn’t see anything

Make a limit on g(v)!

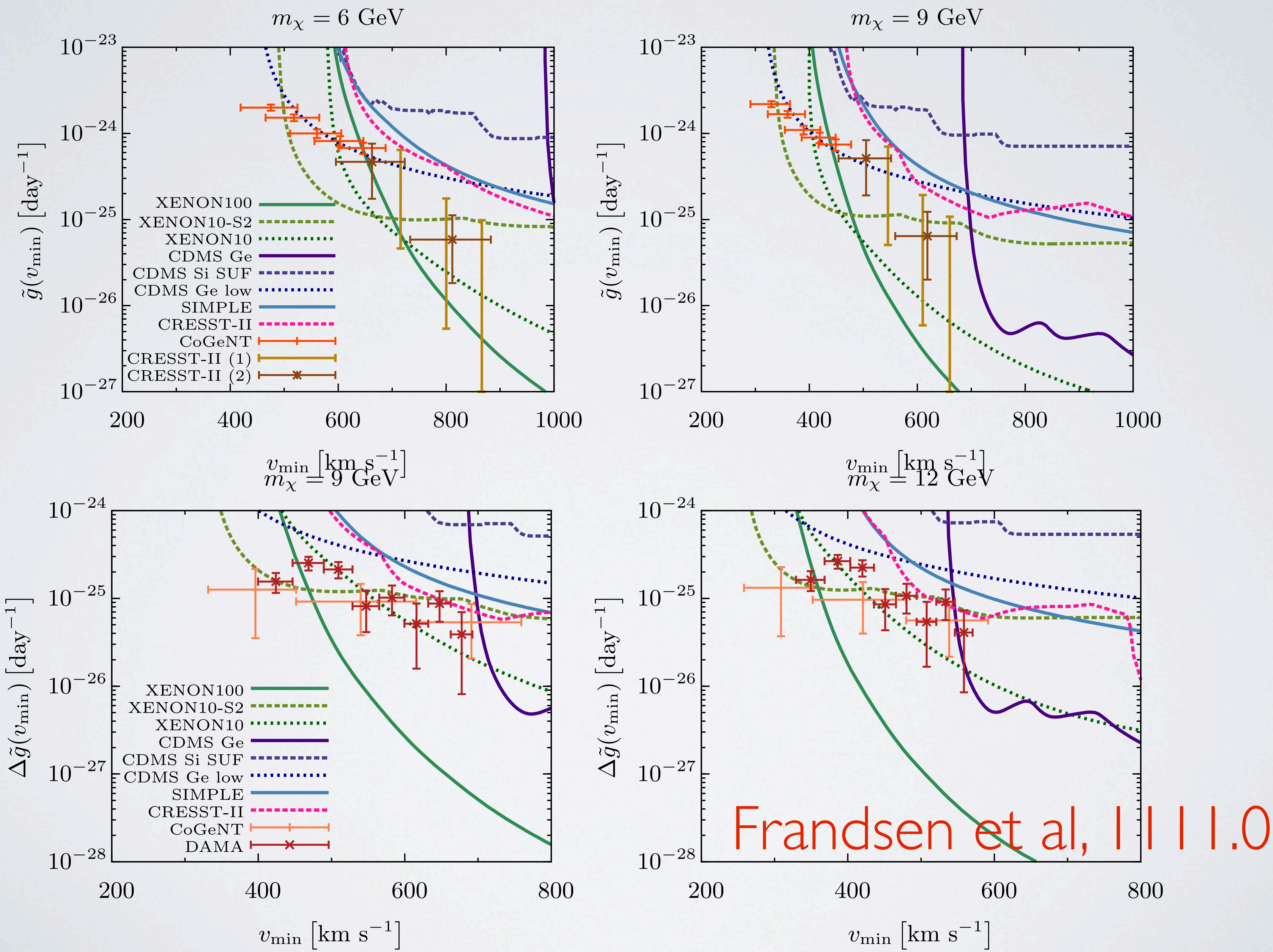
CONSTRAINING G(V)



use monotonicity of g(v) to set limits

$$\frac{dR}{dE_R} = \frac{N_T M_T \rho}{2 m_\chi \mu^2} \sigma(E_R)\, g_1 \Theta(v_1 - v_{min}(E_R))$$

CURRENT LIMITS



Frandsen et al, 1111.0292

IN SUMMARY

- We are motivated to consider light WIMPs (i.e., we are here)
- Light WIMPs very sensitive to the tail of distributions
- Modulation seems present but **very** large
- Need techniques to compare experiments independent of halo model
- Even in those techniques, tensions are obvious