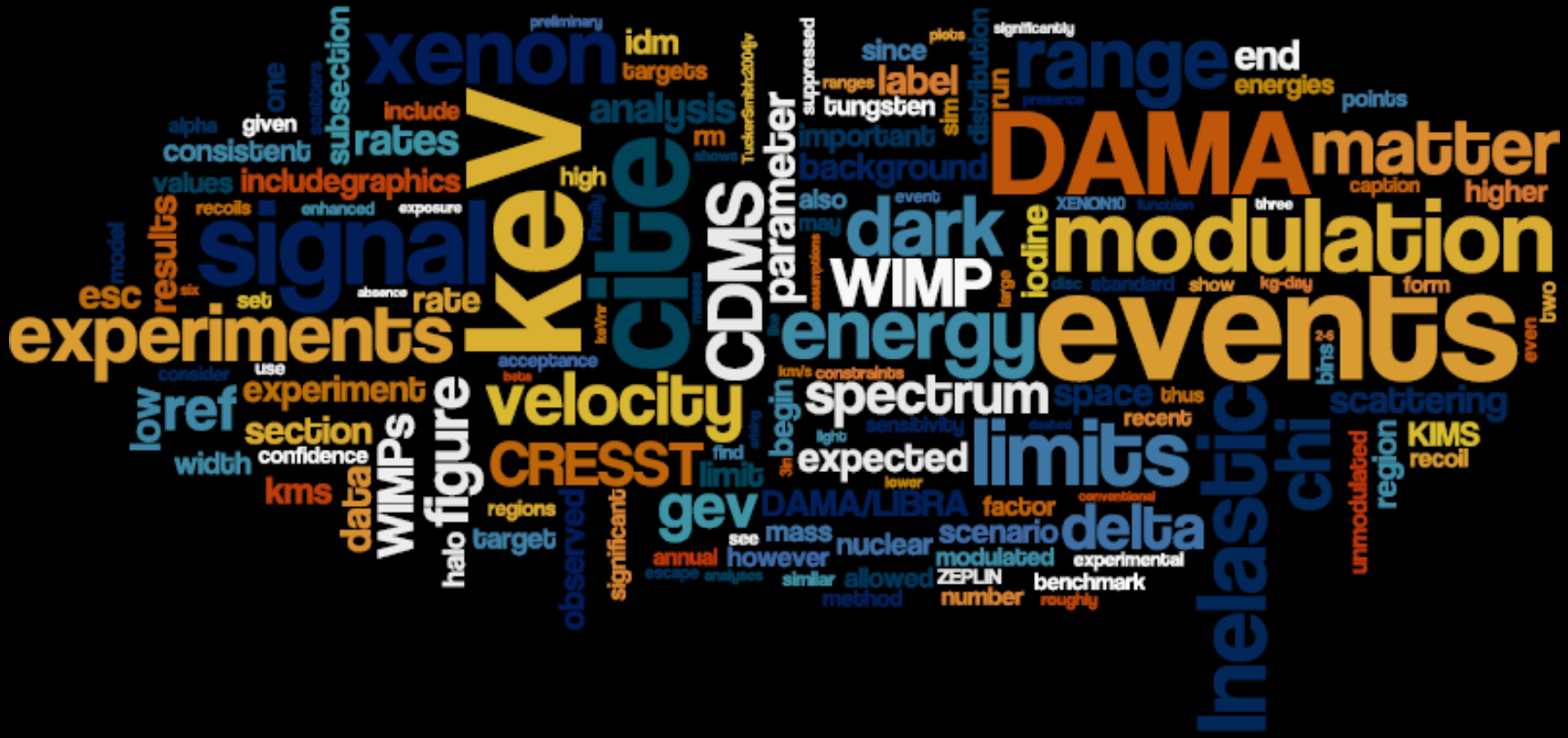
New Physics Interpretation of DAMA Discussion



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work in collaboration with
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D. Tucker-Smith, N. Weiner

hep-ph:0807.2250
hep-ph:0808.0196

Potential Models of Discussion

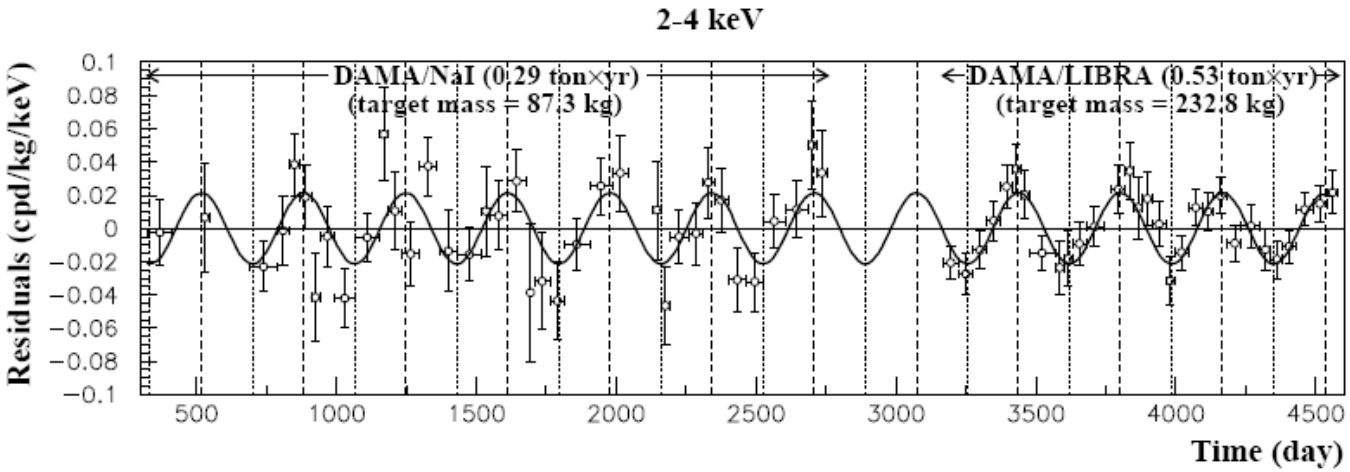
- Published Work
  - Light Dark Matter
  - Inelastic Dark Matter
- Work in progress
  - Inelastic Dark Matter with light mediator
  - Electron Interacting Dark Matter

Note: Won't discuss spin-dependent cases

DAMA Goggles

- DAMA/LIBRA data is now good enough to pin down parameter space of dark matter candidates
- What is new
  - Single hit, unmodulated spectra
  - Finely binned modulation spectra

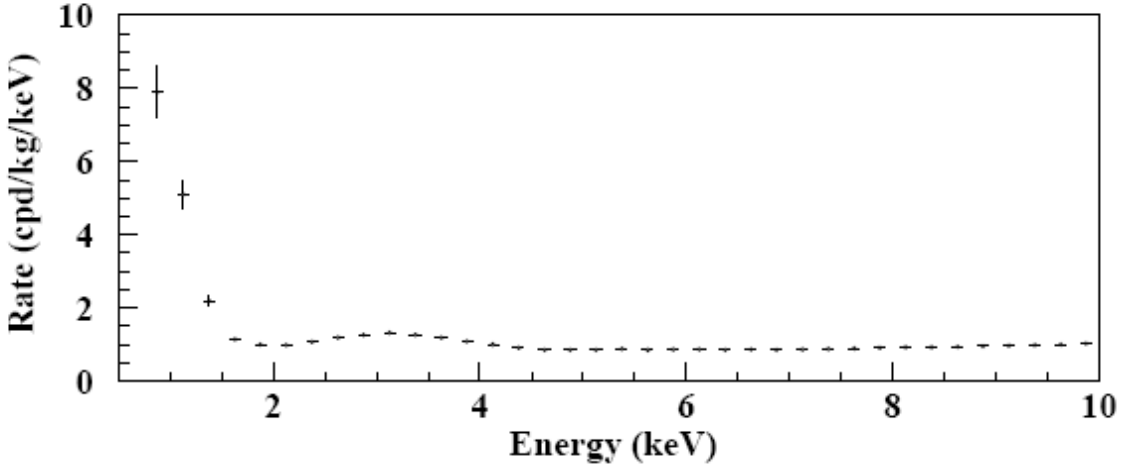
Data Consistent with DM modulation



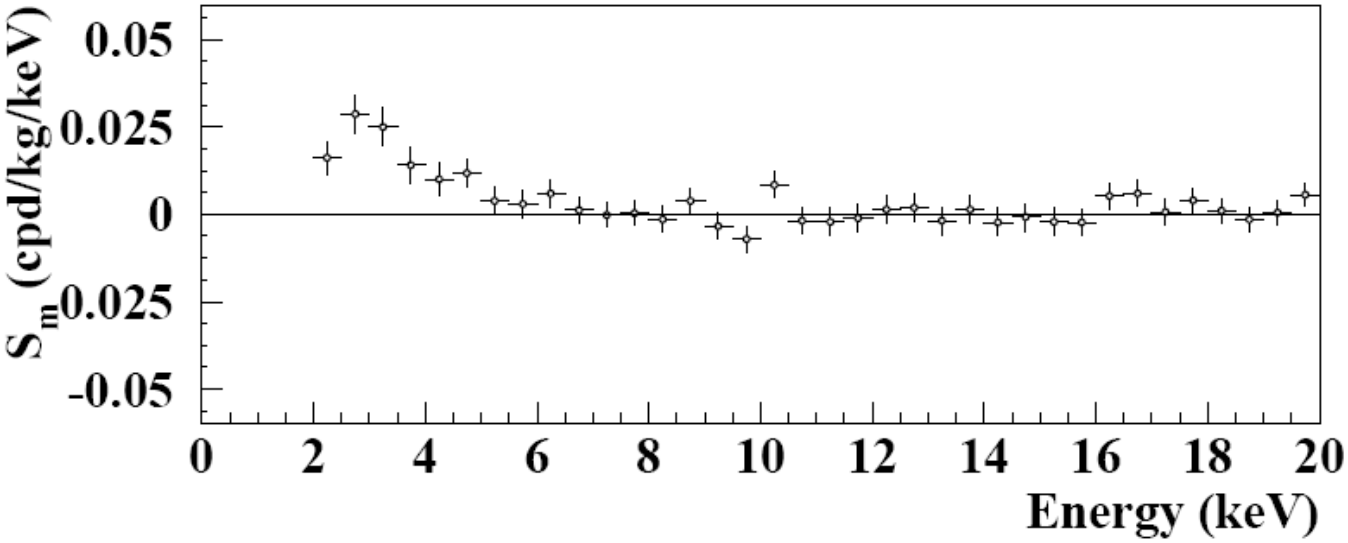
	A (cpd/kg/keV)	$T = \frac{2\pi}{\omega}$ (yr)	t_0 (day)	C.L.
DAMA/NaI				
(2–4) keV	0.0252 ± 0.0050	1.01 ± 0.02	125 ± 30	5.0σ
(2–5) keV	0.0215 ± 0.0039	1.01 ± 0.02	140 ± 30	5.5σ
(2–6) keV	0.0200 ± 0.0032	1.00 ± 0.01	140 ± 22	6.3σ
DAMA/LIBRA				
(2–4) keV	0.0213 ± 0.0032	0.997 ± 0.002	139 ± 10	6.7σ
(2–5) keV	0.0165 ± 0.0024	0.998 ± 0.002	143 ± 9	6.9σ
(2–6) keV	0.0107 ± 0.0019	0.998 ± 0.003	144 ± 11	5.6σ
DAMA/NaI+ DAMA/LIBRA				
(2–4) keV	0.0223 ± 0.0027	0.996 ± 0.002	138 ± 7	8.3σ
(2–5) keV	0.0178 ± 0.0020	0.998 ± 0.002	145 ± 7	8.9σ
(2–6) keV	0.0131 ± 0.0016	0.998 ± 0.003	144 ± 8	8.2σ
	Expectations	1	152	

Spectras

Overall Rate



Modulation Amplitude



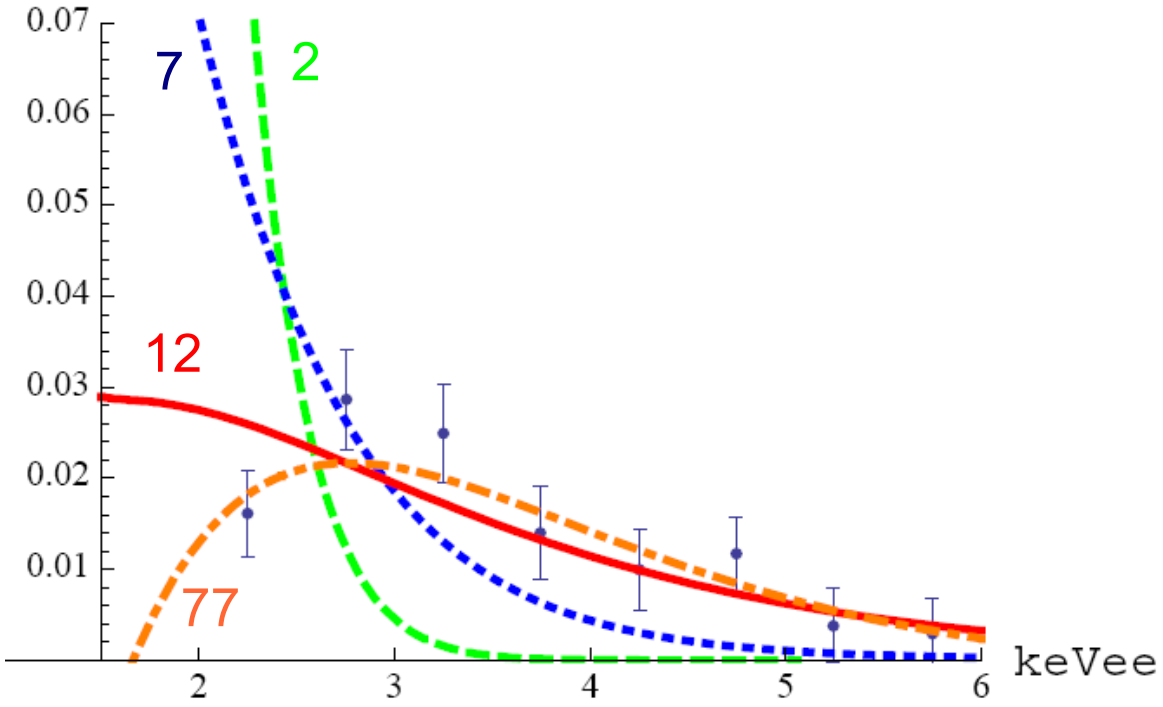
My Mantra

- Overall rate has very little background discrimination
  - Expect O(1) contamination
  - But can be agnostic about its form as long as you don't exceed it
- Modulation rate spectra is detailed
  - Predicts preferred regions of DM
  - Can then check if other experiments are consistent

Elastic DM

SC, Pierce, Weiner
See also Fairbairn, Schwetz

DAMA spectra for different masses (GeV)

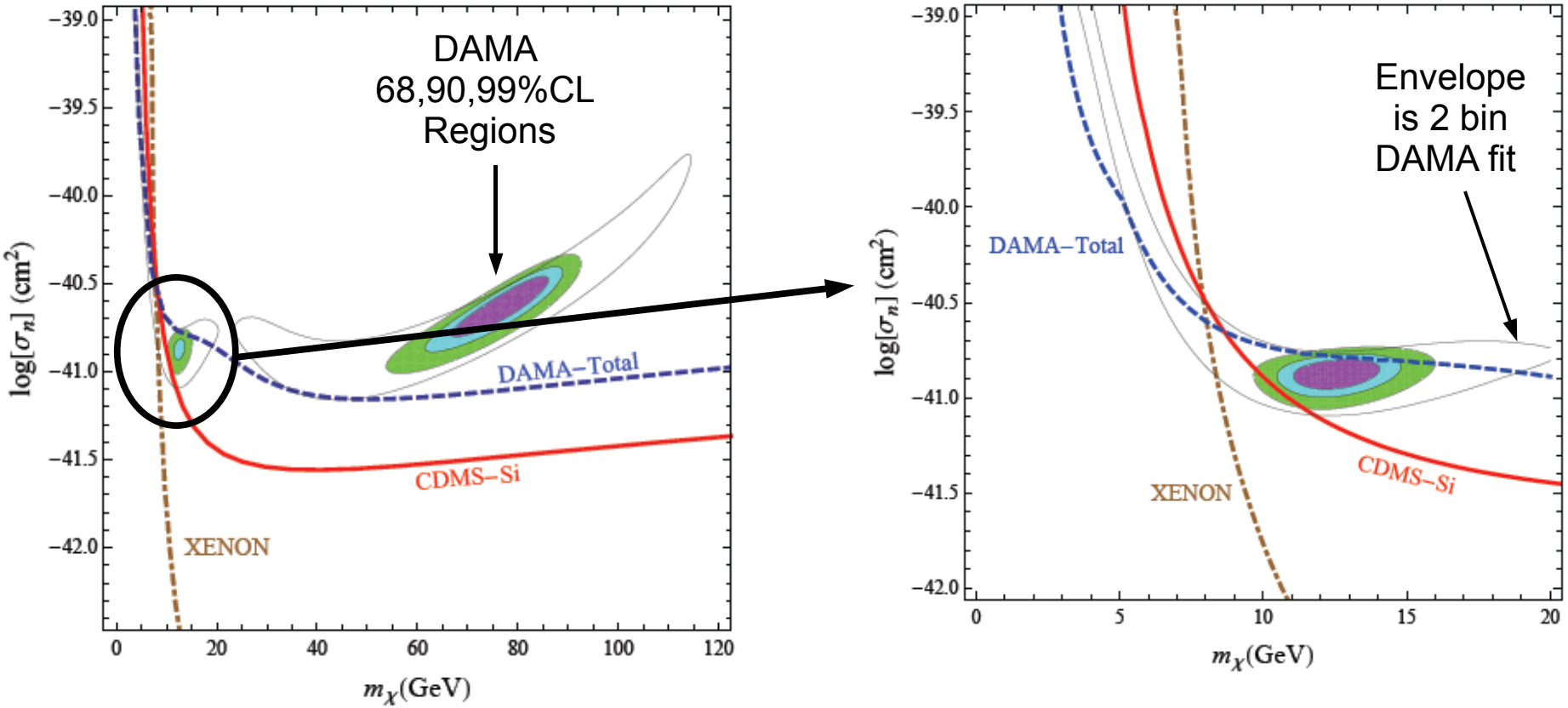


Data points pick out preferred mass regions

Fact that the first few points are “low” drives the fit

LDM Plots

SC, Pierce, Weiner



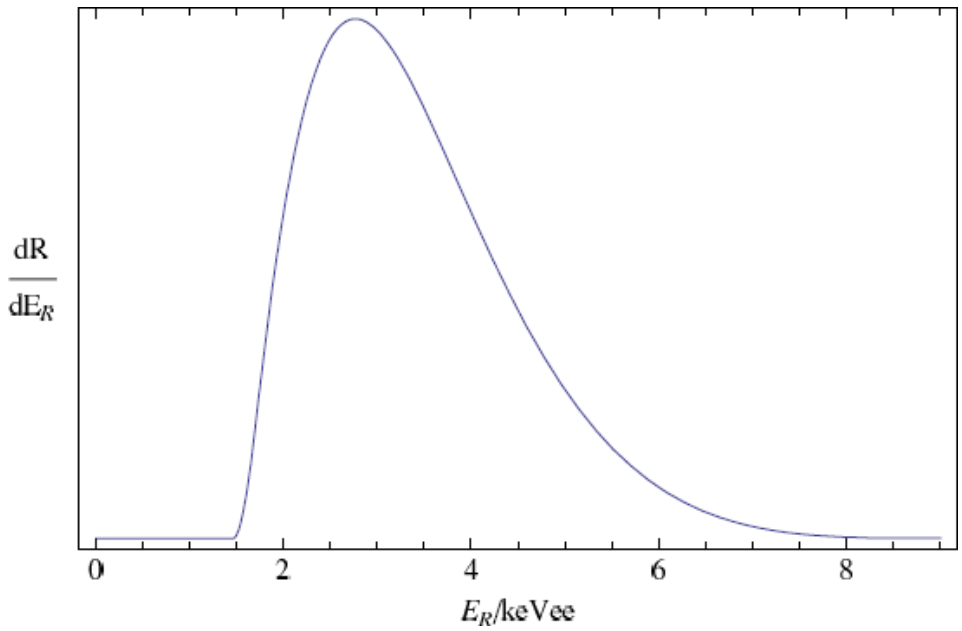
Spectral information disfavors m < 10 GeV
Need nonstandard astrophysics/expt'l issues for consistency

Inelastic Dark Matter

- Models where dark matter scatters dominantly inelastically off nuclei
- Adds extra parameter δ, mass splitting to heavier state
- Kinematics produces a few effects

Distinct Spectra

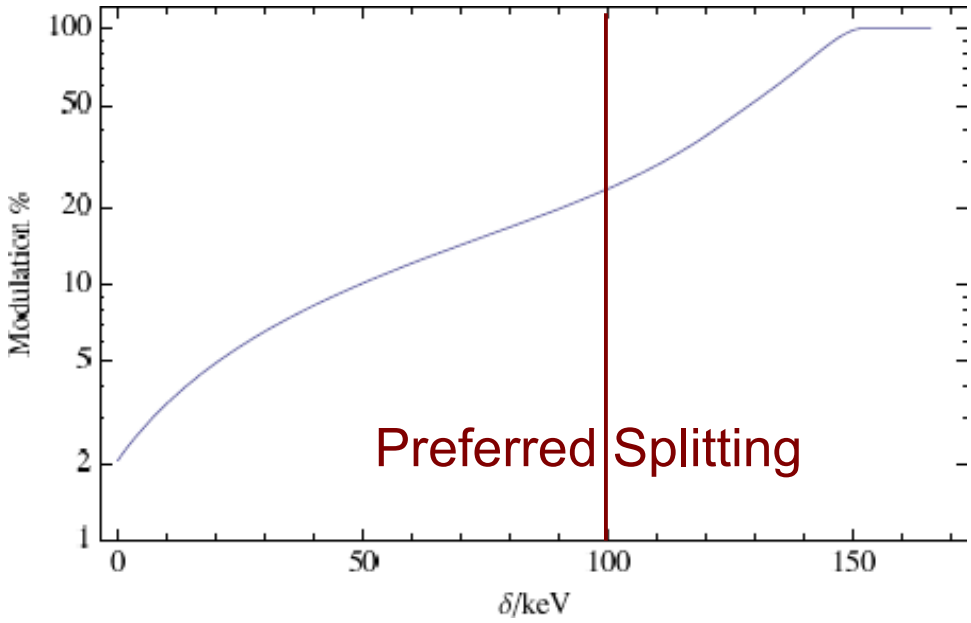
$$\beta_{min} = \frac{1}{\sqrt{2\, m_N E_R}} \left(\frac{m_N E_R}{\mu_N} + \delta \right)$$



- Minimum velocity is changed
  - Low Energy recoils suppressed b/c they require higher velocity
  - Heavier targets have smaller threshold velocity

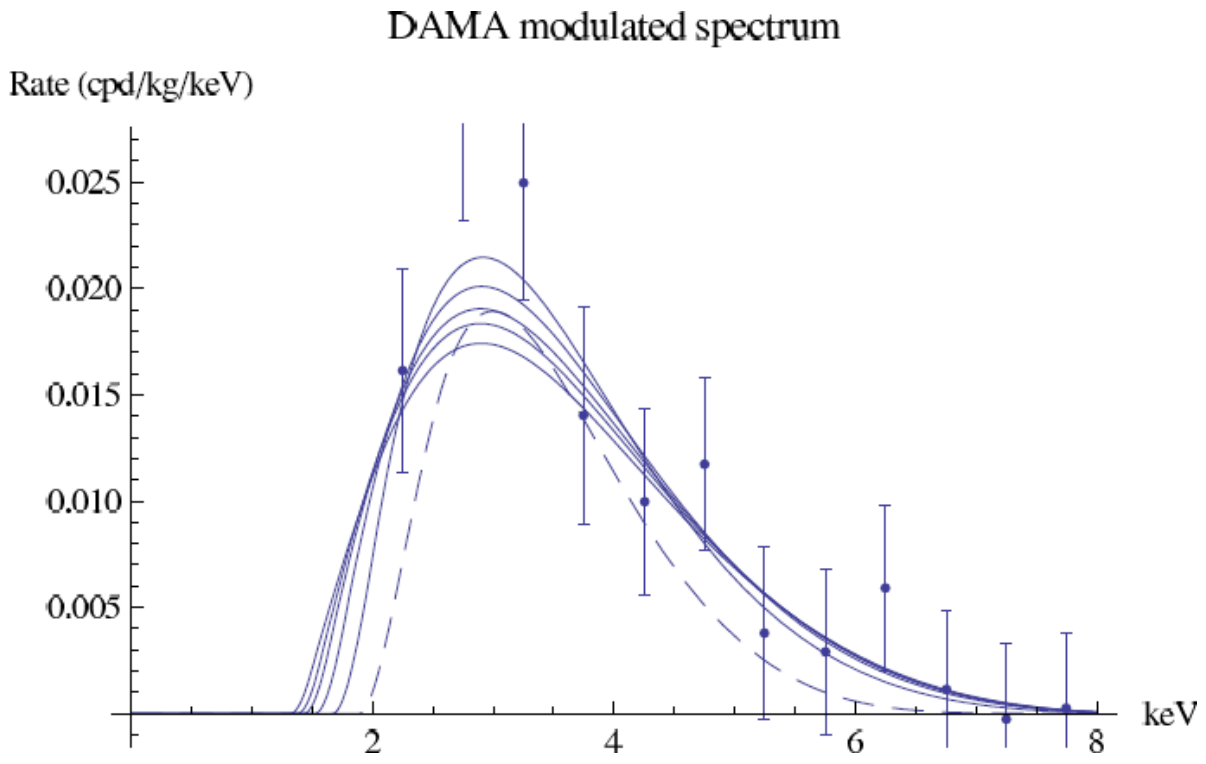
Enhanced Modulation

- Sampling of higher velocity tail, means more modulation
- Expt: Dates of data taking crucial to setting limits. Can search for enhanced modulation



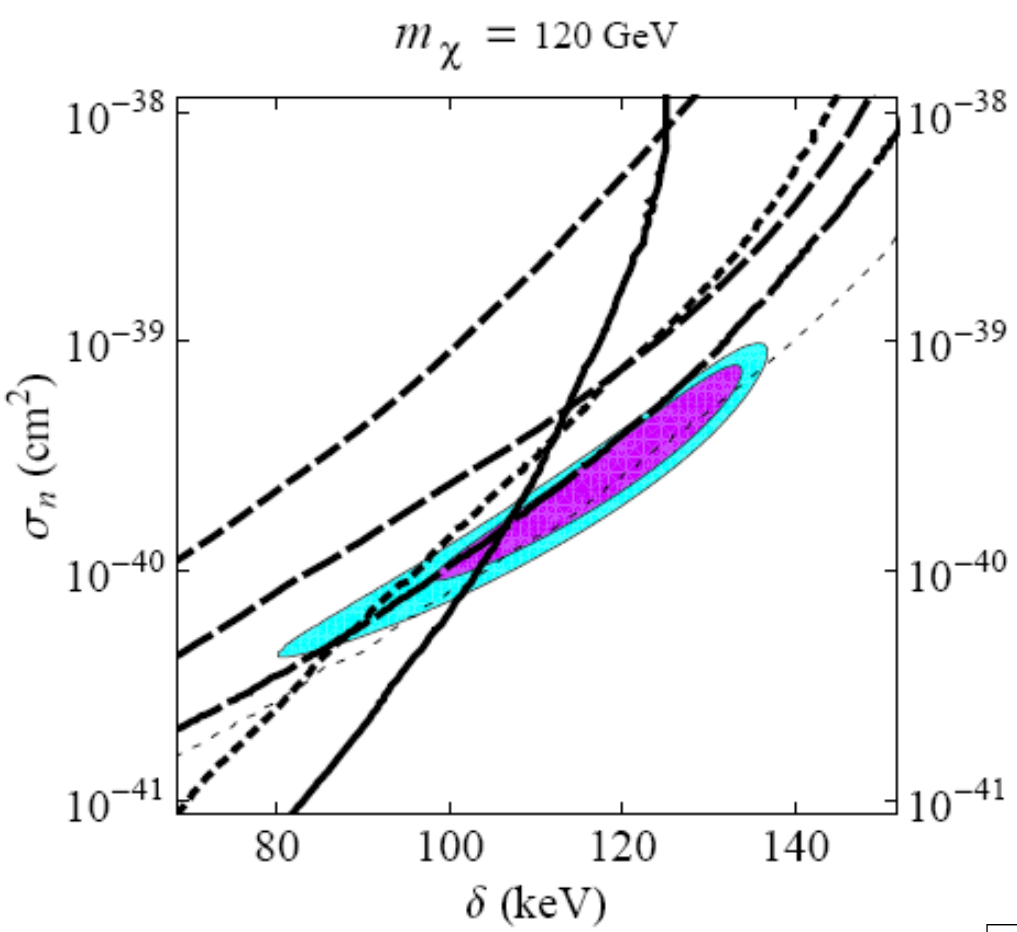
Modulation in observed DAMA range

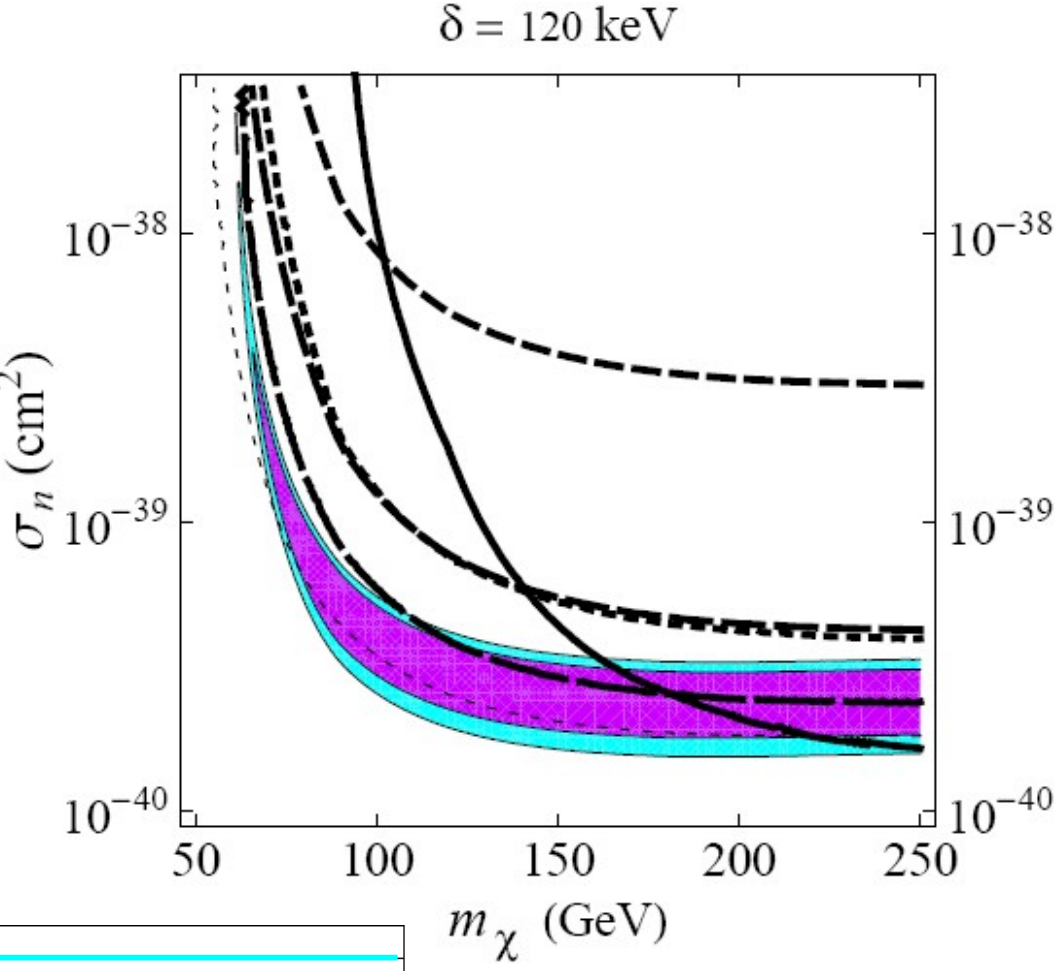
DAMA Spectra Benchmarks

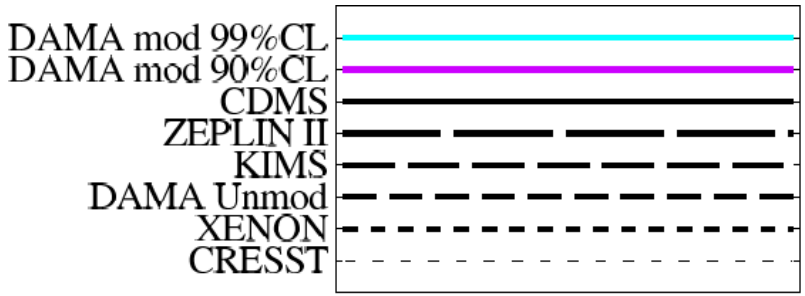


For different dark matter masses, each fit prefers a range for δ, as it shifts the peak

IDM Plots



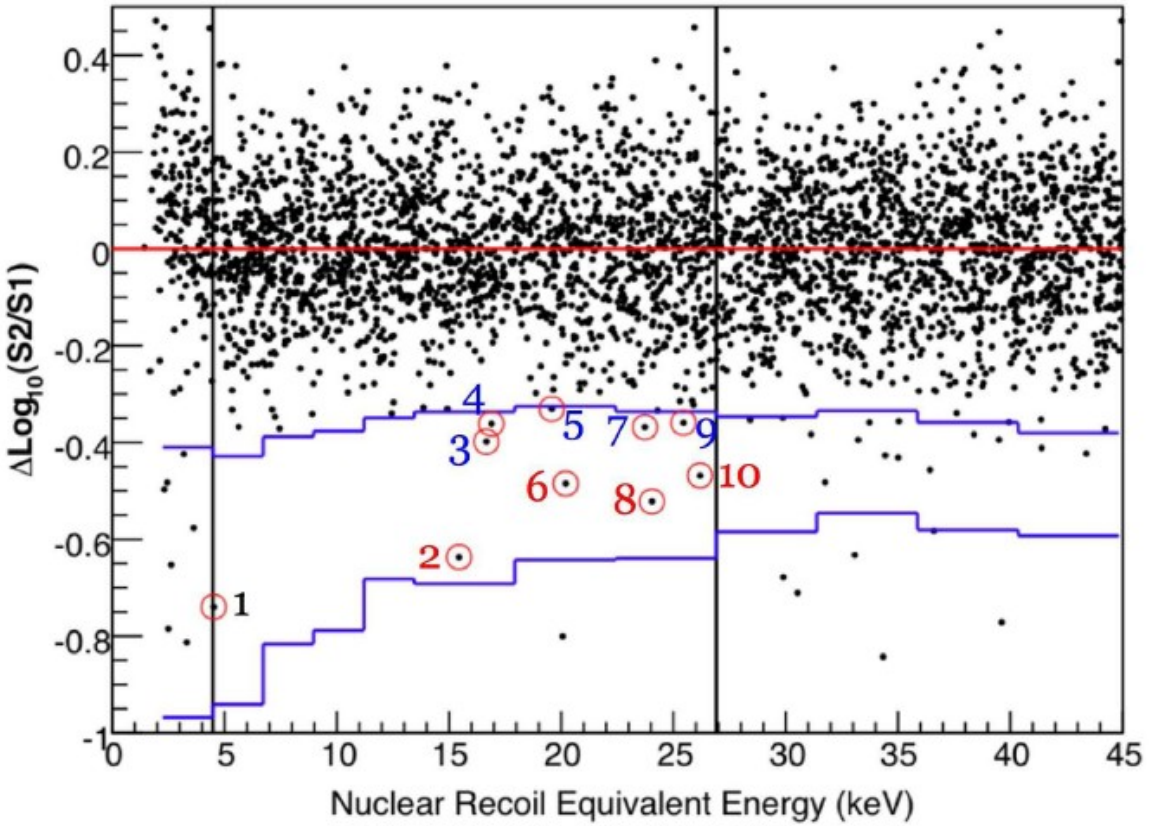




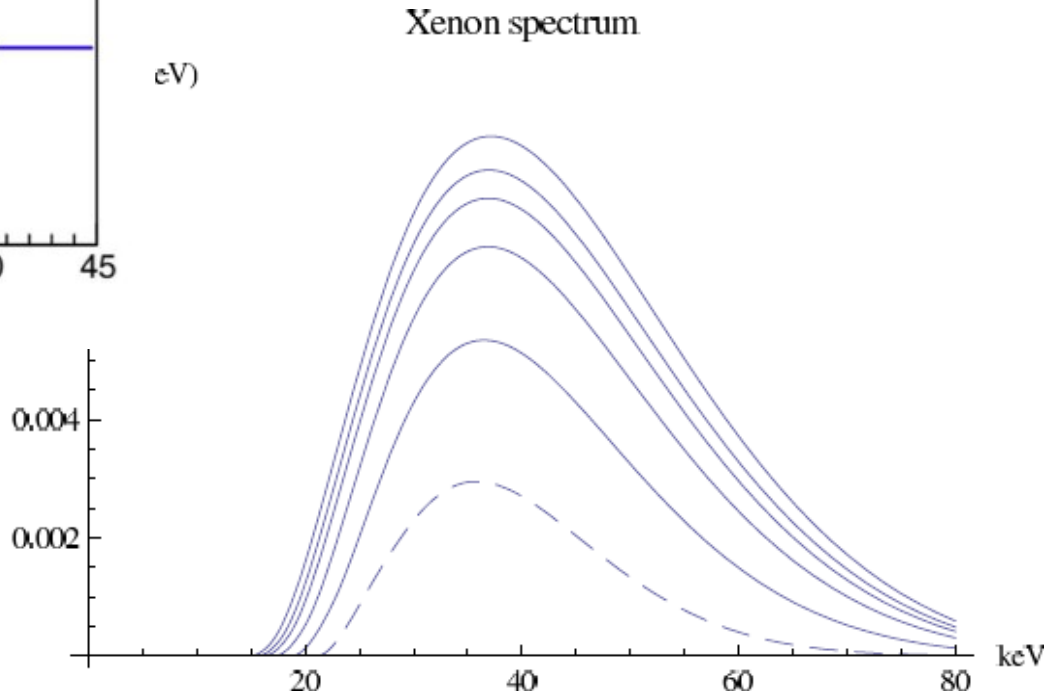
Constraints are p_{max} (Yellin)

CRESST and ZEPLIN strongest!

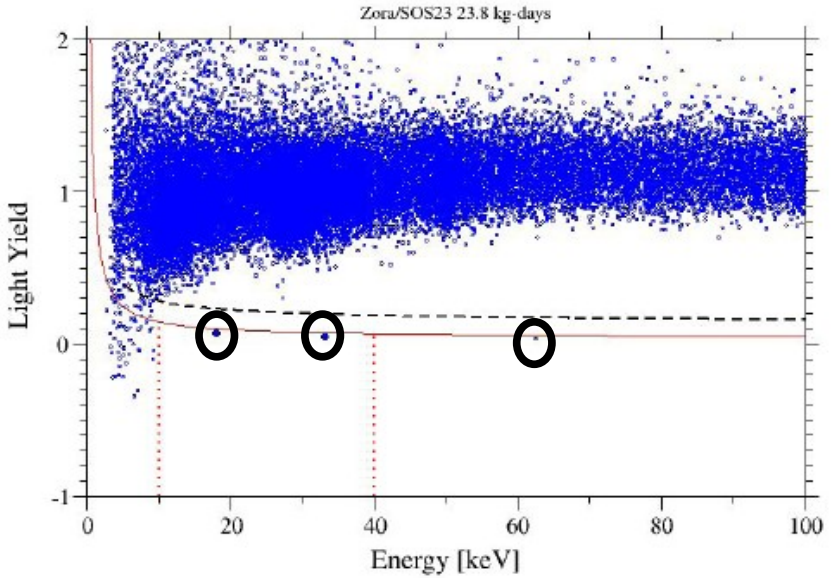
XENON Data

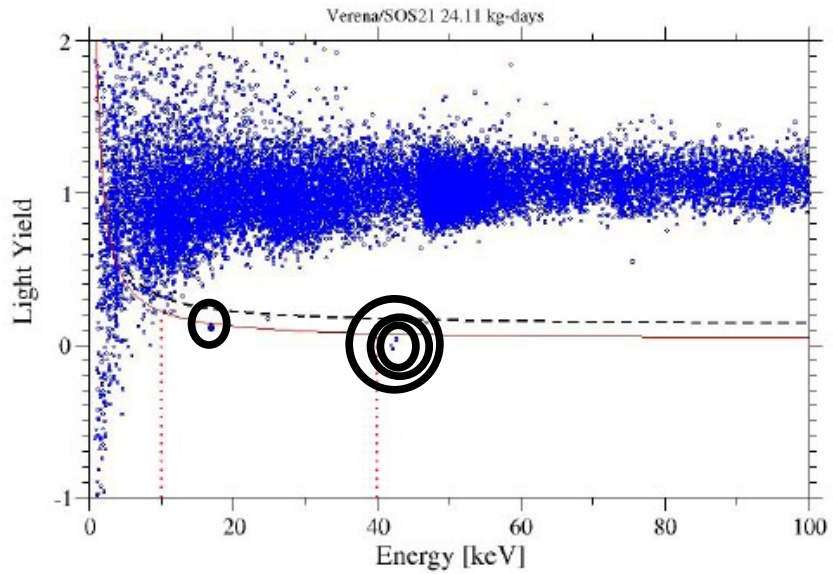


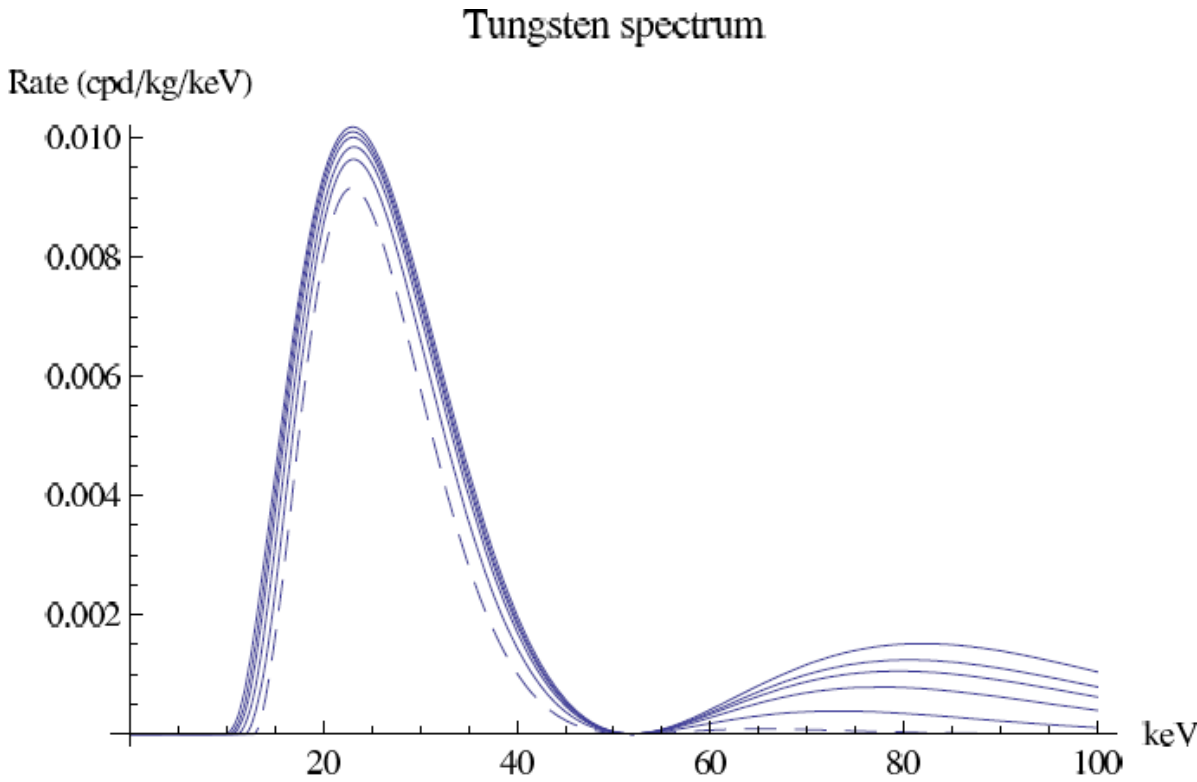
Analysis region (< 27 keV) misses most of the IDM recoils



CRESST Data







Form factor behavior is crucial

Events inconsistent with expected background

Benchmark Values

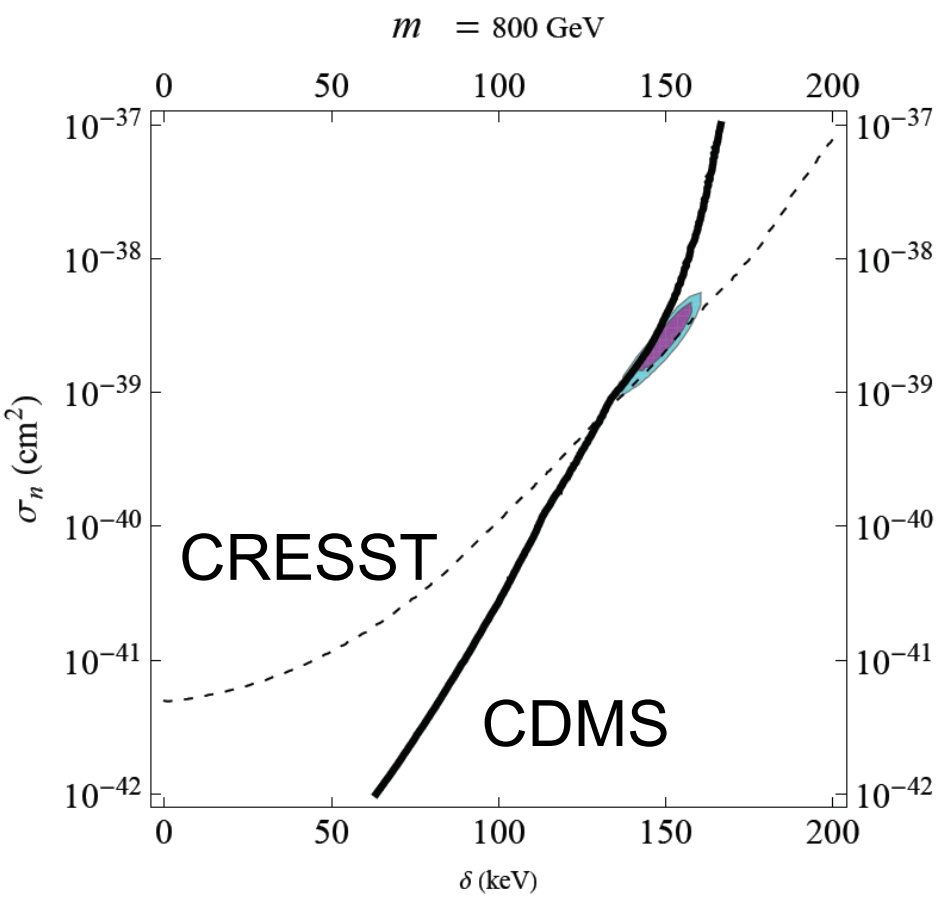
#	m_χ (GeV)	σ_n (10^{-40} cm^2)	δ (keV)	DAMA 2-6 keVee (10^{-2} dru)	XENON 4.5-45 keV (counts)	CDMS 10-100 keV (counts)	ZEPLIN 5-20 keVee (counts)	KIMS 3-8 keVee (10^{-2} dru)	CRESST 12-100 keV (counts)
expt				1.31 ± 0.16	24 (31.6)	2 (5.3)	29 (37.2)	5.65 ± 3.27	7 (11.8)
1	70	11.85	119	0.89	1.39	0	8.46	0.65	8.76
2	90	5.75	123	1.21	5.52	0	14.40	1.52	9.75
3	120	3.63	125	1.22	9.06	0.13	18.09	2.18	10.7
4	150	2.92	126	1.18	11.17	0.95	19.93	2.53	11.2
5	180	2.67	126	1.15	12.46	1.93	21.01	2.74	11.6
6	250	2.62	127	1.11	14.01	3.60	23.32	3.00	12.1

Theory of Dark Matter

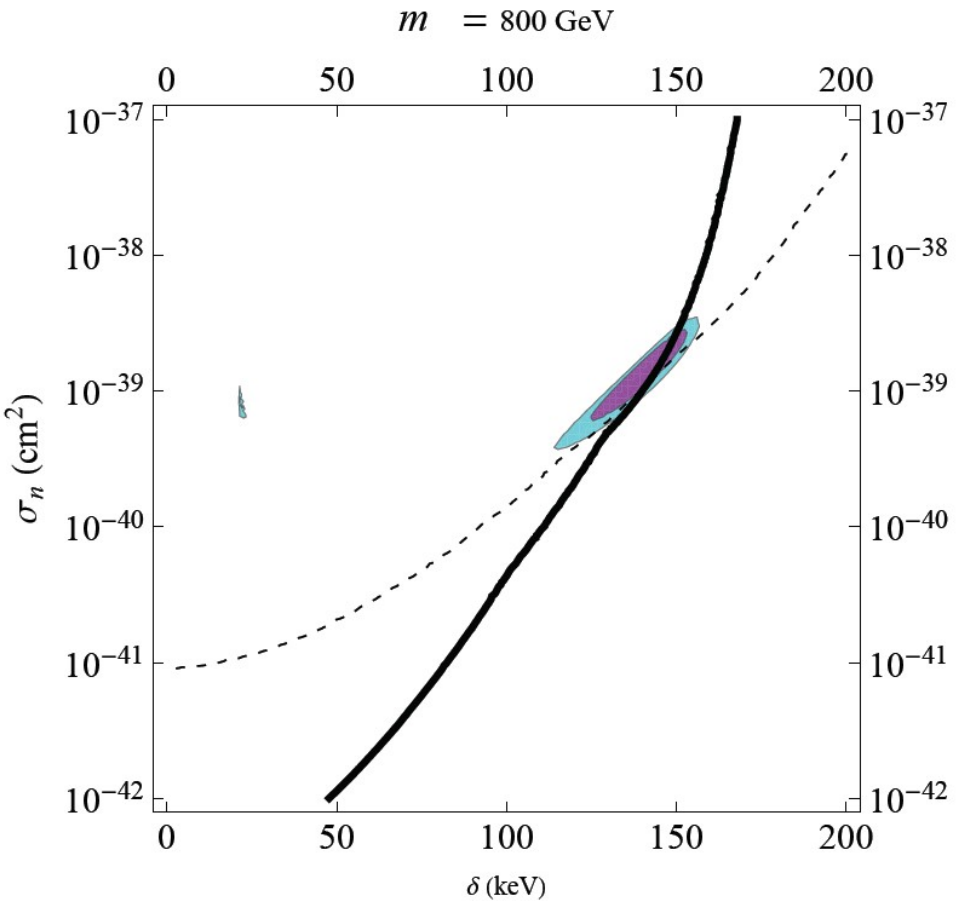
- Dark matter mass due to ATIC is 800 GeV – 1 TeV
- Attempts to get DAMA by inelastic scattering
  - Plots from before rule out m > 250 GeV
- However, the inelastic scattering is mediated by light vector ϕ, giving $1/(q^2 - m_\phi{}^2)^2$ in rate

Preliminary Results: Pushes to larger δ

$m_\phi \sim 8$ MeV



$m_\phi \sim 80$ MeV



Electron Recoils

- My suspicion is that the spectra does not fit for weak scale DM masses
- If interested, let's talk offline

Conclusions

- DAMA's new data is predictive enough to set up a (hopefully) non-moving target
- Light Dark Matter
  - Low threshold expts: CDMS, CoGeNT, and even XENON will further constrain
- Inelastic Dark Matter
  - Heavy target expts: CRESST, XENON, LUX, KIMS, ZEPLIN should see high energy events and possibly modulation