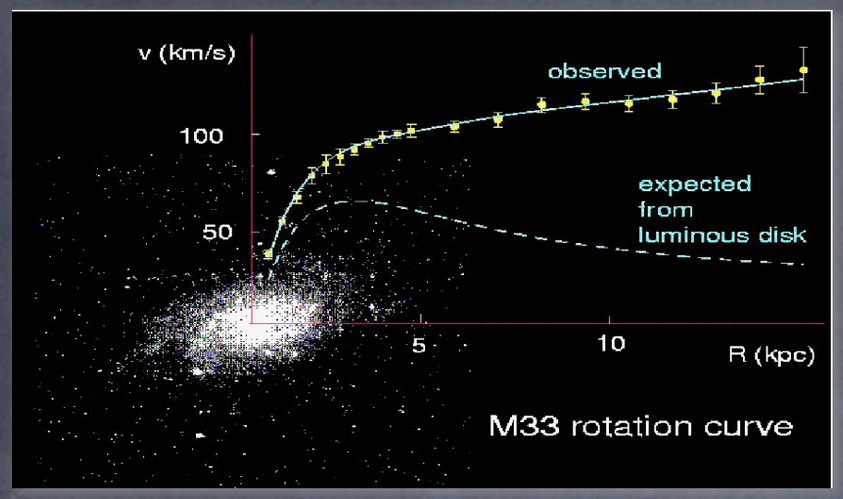
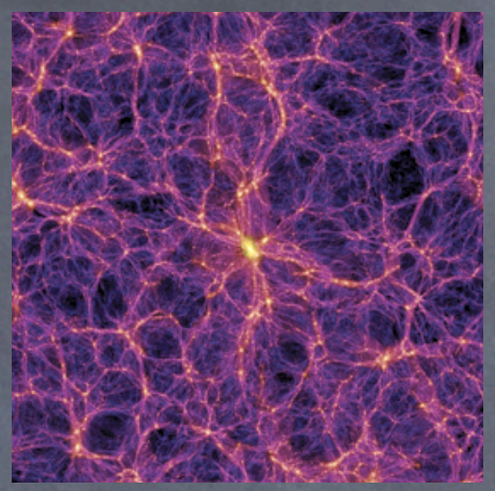
IVDM

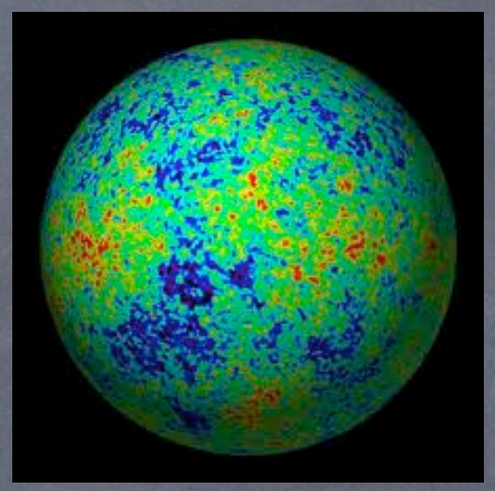
Danny Marfatia

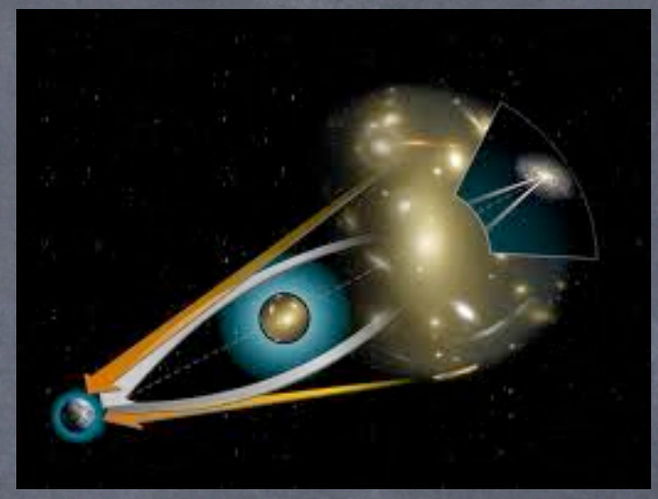
with Feng, Kumar, Sanford 1102.4331

Evidence is gravitational







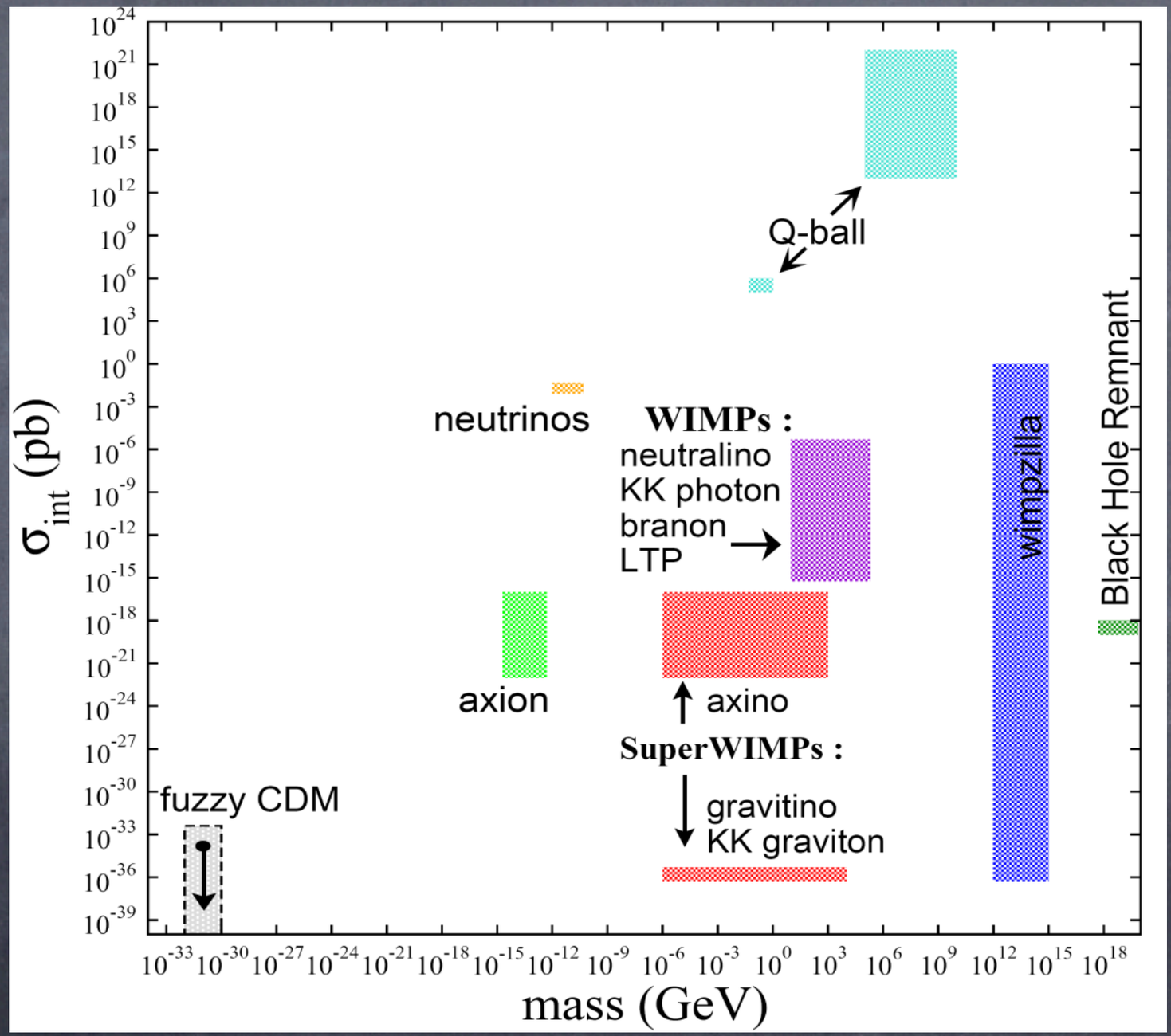


- Galactic rotation curves
- Large scale structure
- Cosmic microwave background anisotropies
- Gravitational lensing

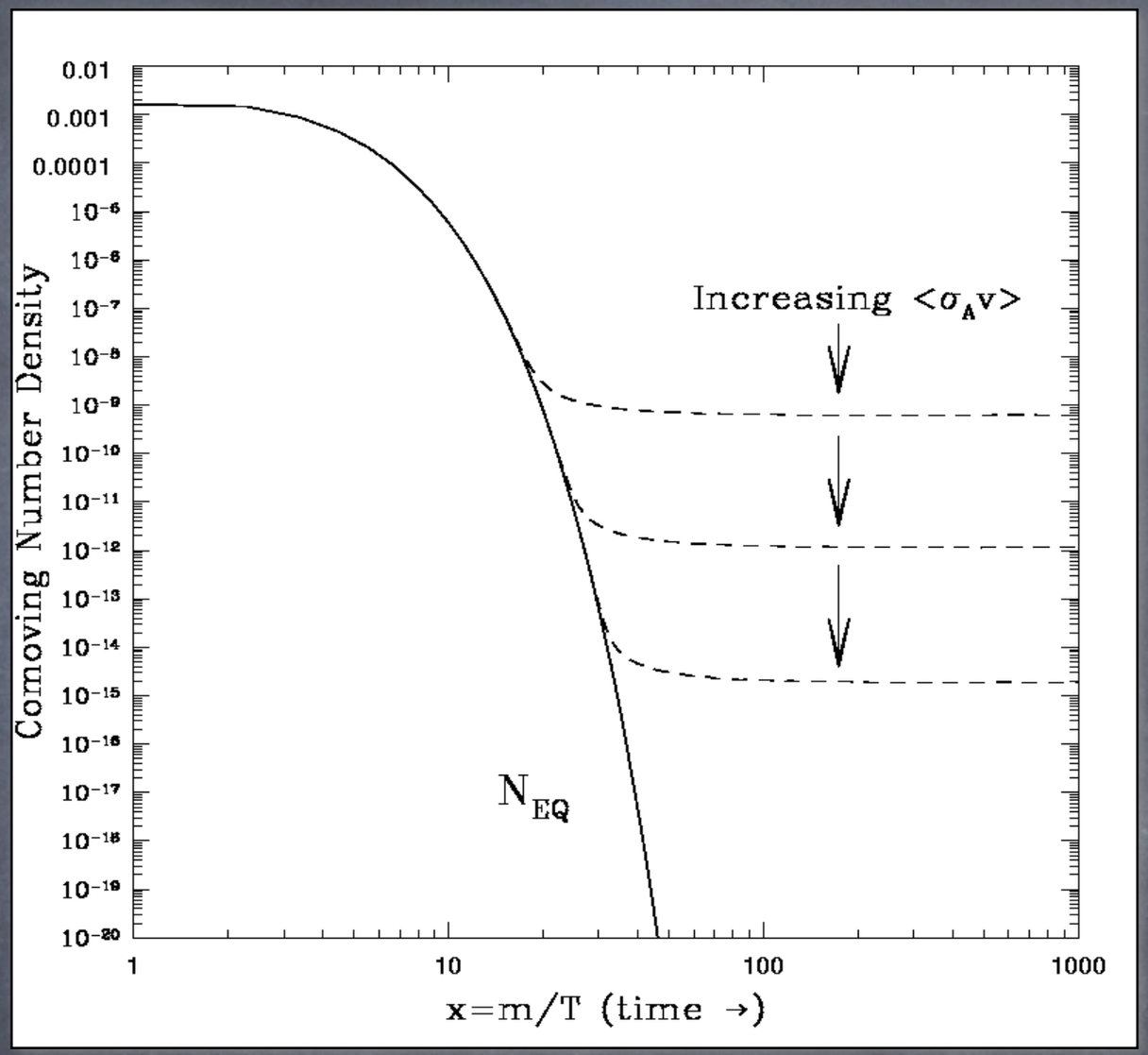
Little is known about dark matter

- Abundance is 23%
- Long-lived
- Not hot
- Not baryonic

Too many candidates?



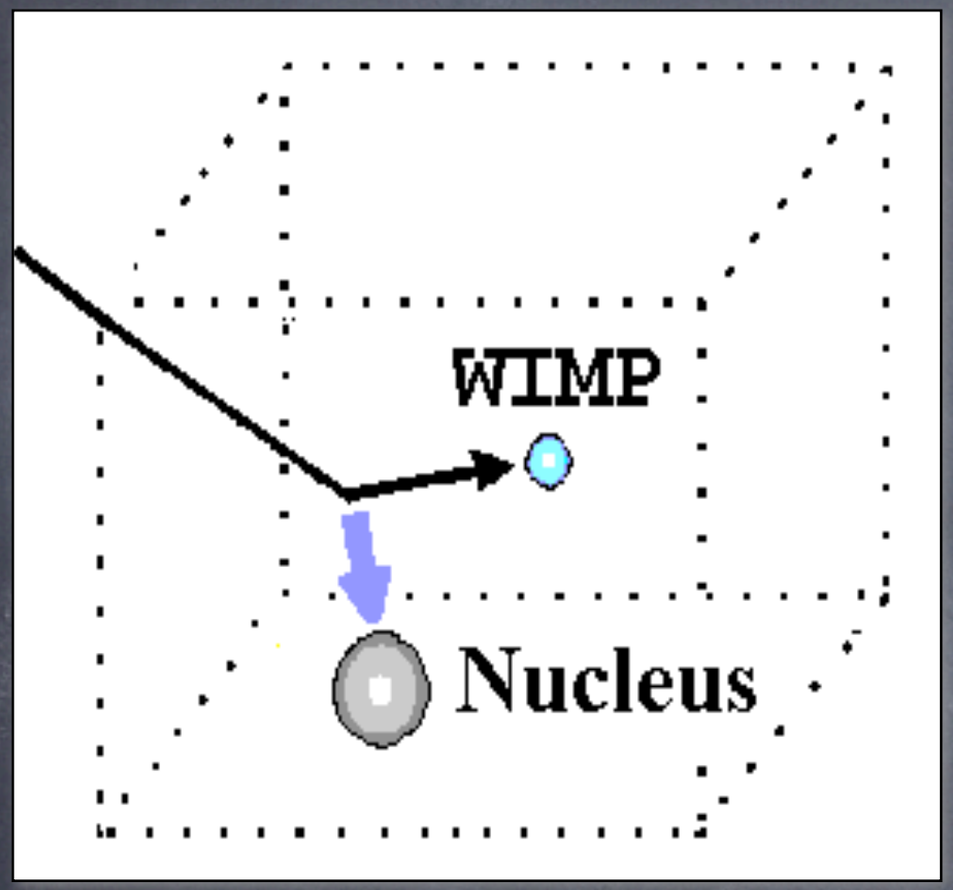
The WIMP miracle is aesthetically pleasing



$$\langle \sigma v \rangle = 3 \times 10^{-26} \mathrm{cm}^3/\mathrm{s}$$

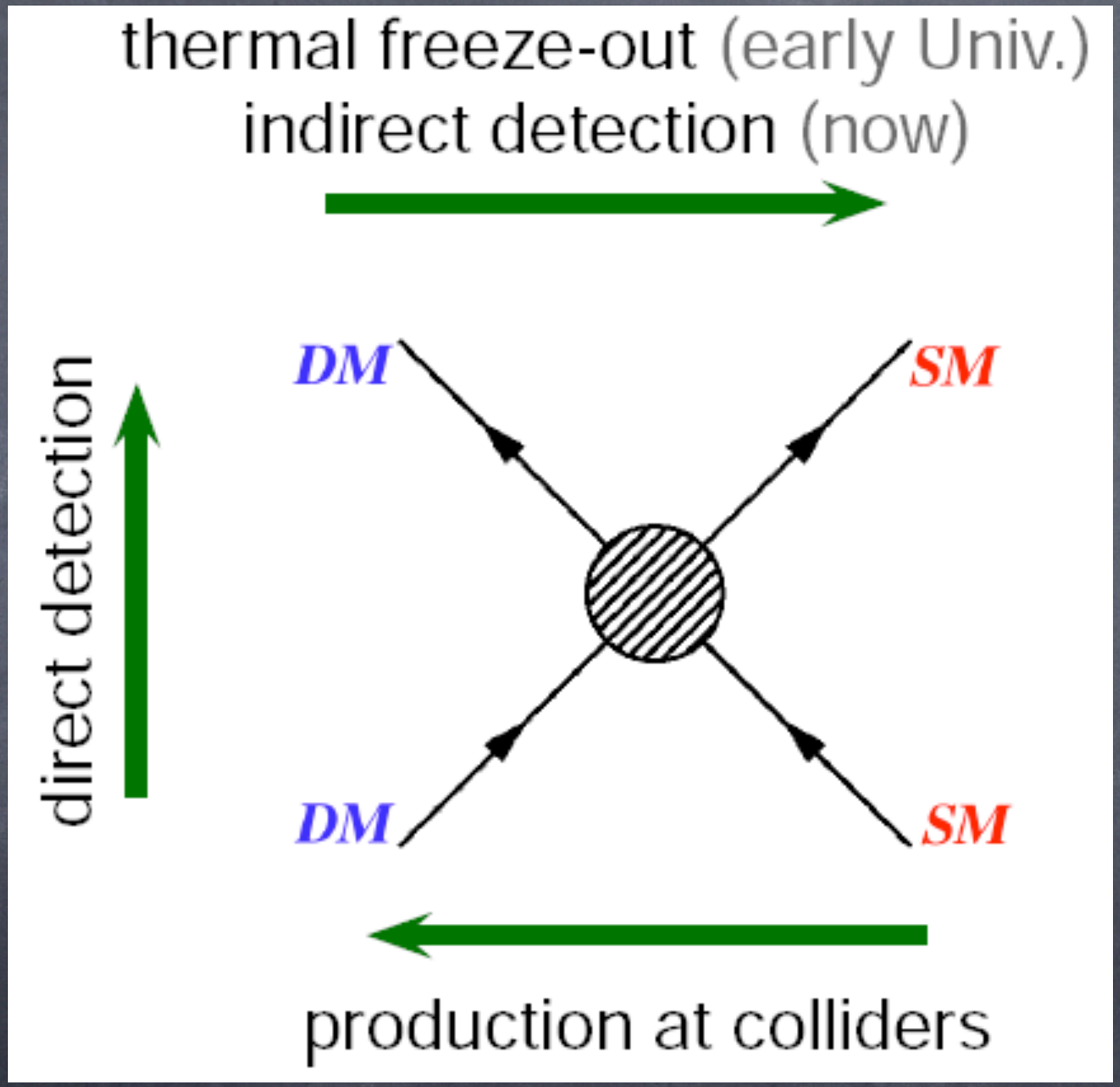
- required to get the correct relic denisty
- obtained with weak scale masses and couplings

Today dark matter physics is anomaly driven!

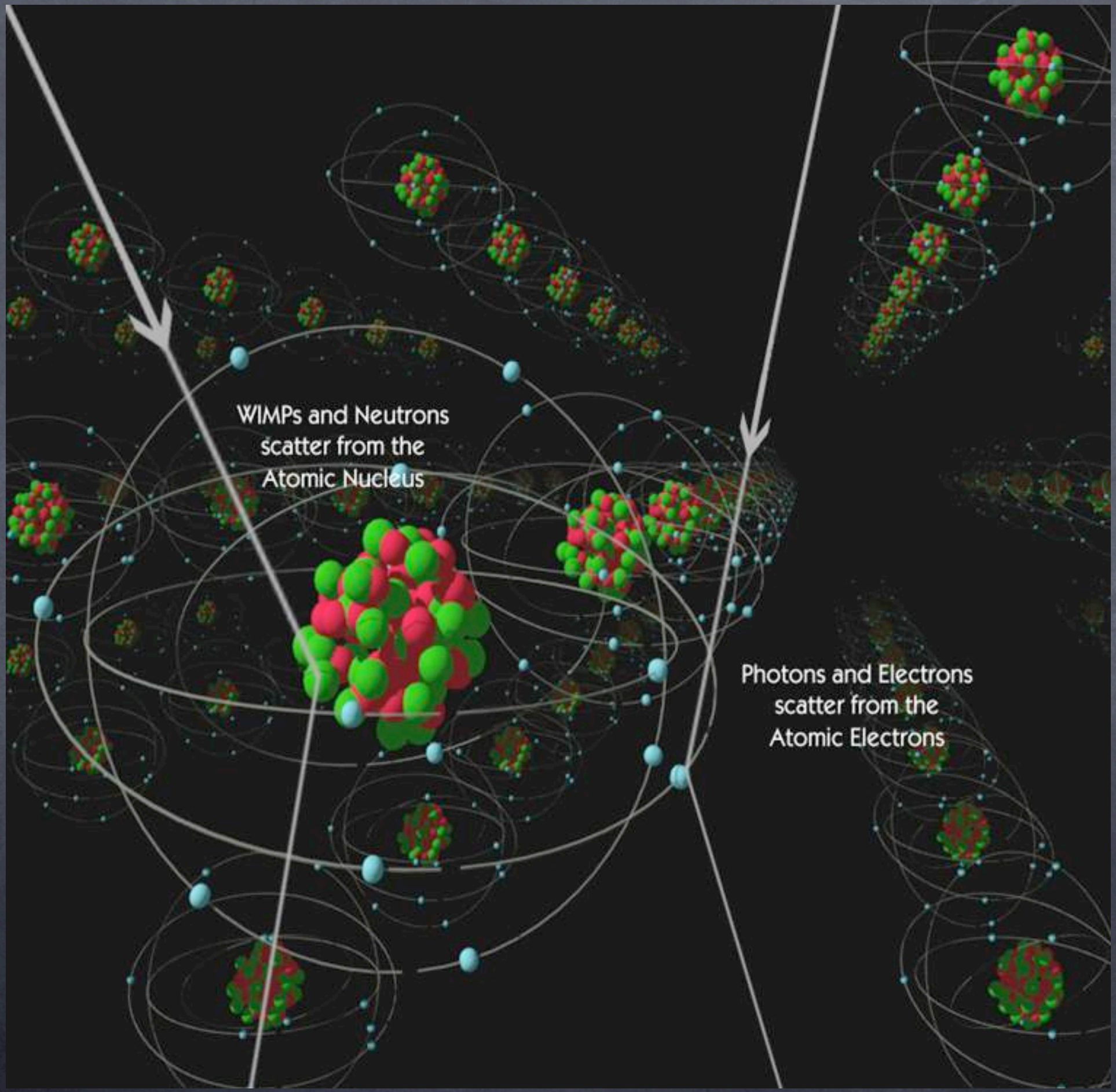


Direct detection

Indirect detection


thermal freeze-out (early Univ.)
indirect detection (now)
direct detection
DM
SM
DM
SM
production at colliders

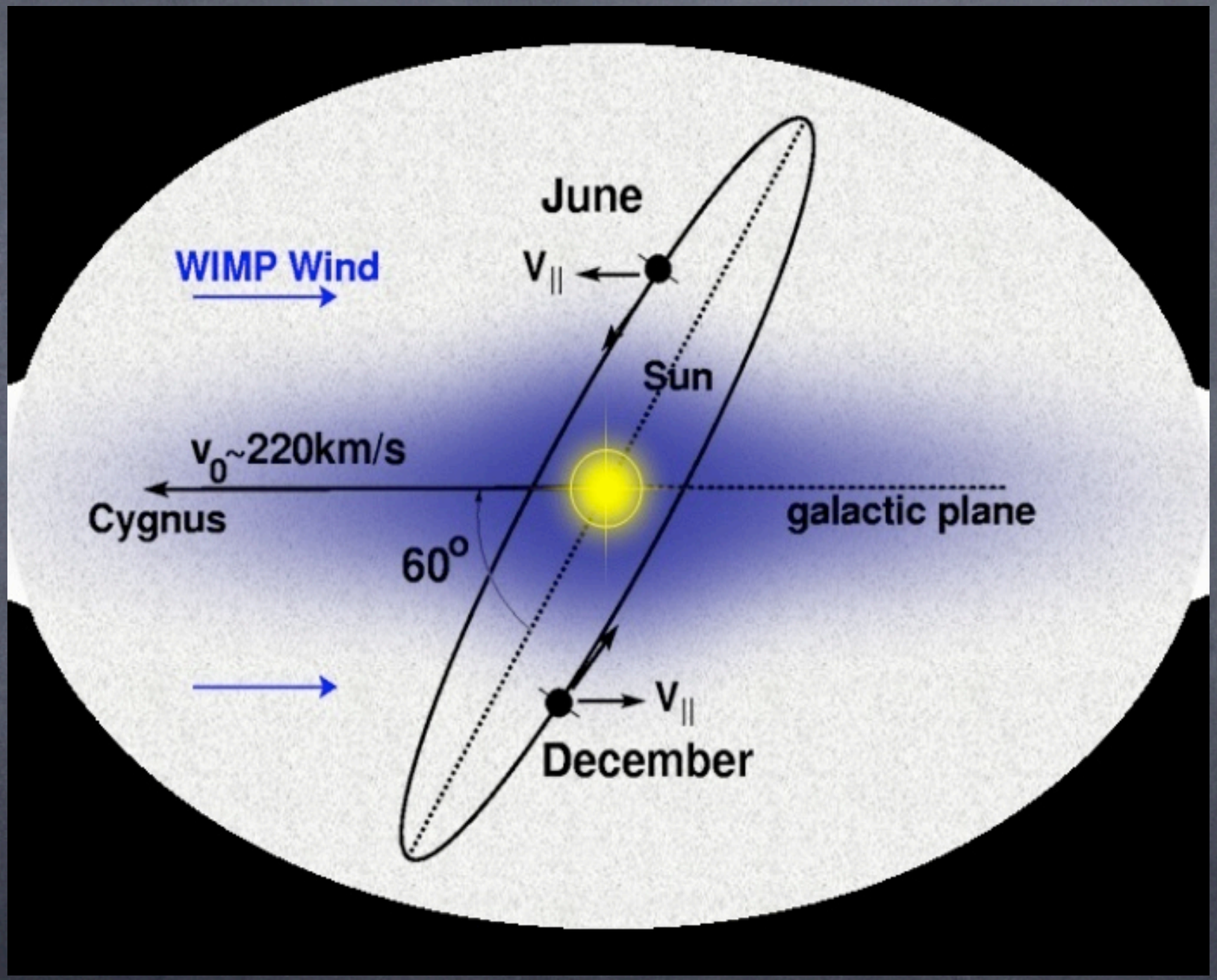
Direct detection


WIMPs and Neutrons
scatter from the
Atomic Nucleus
Photons and Electrons
scatter from the
Atomic Electrons

Scattering cross section

- SI: $\sigma_A \propto [f_p Z + f_n (A - Z)]^2$
- $f_n = f_p \implies \sigma_A \propto [f_p A]^2$
- No reason to assume $f_n = f_p$
- For $f_n / f_p = \dfrac{-Z}{A - Z}$, $\quad \sigma_A = 0$!

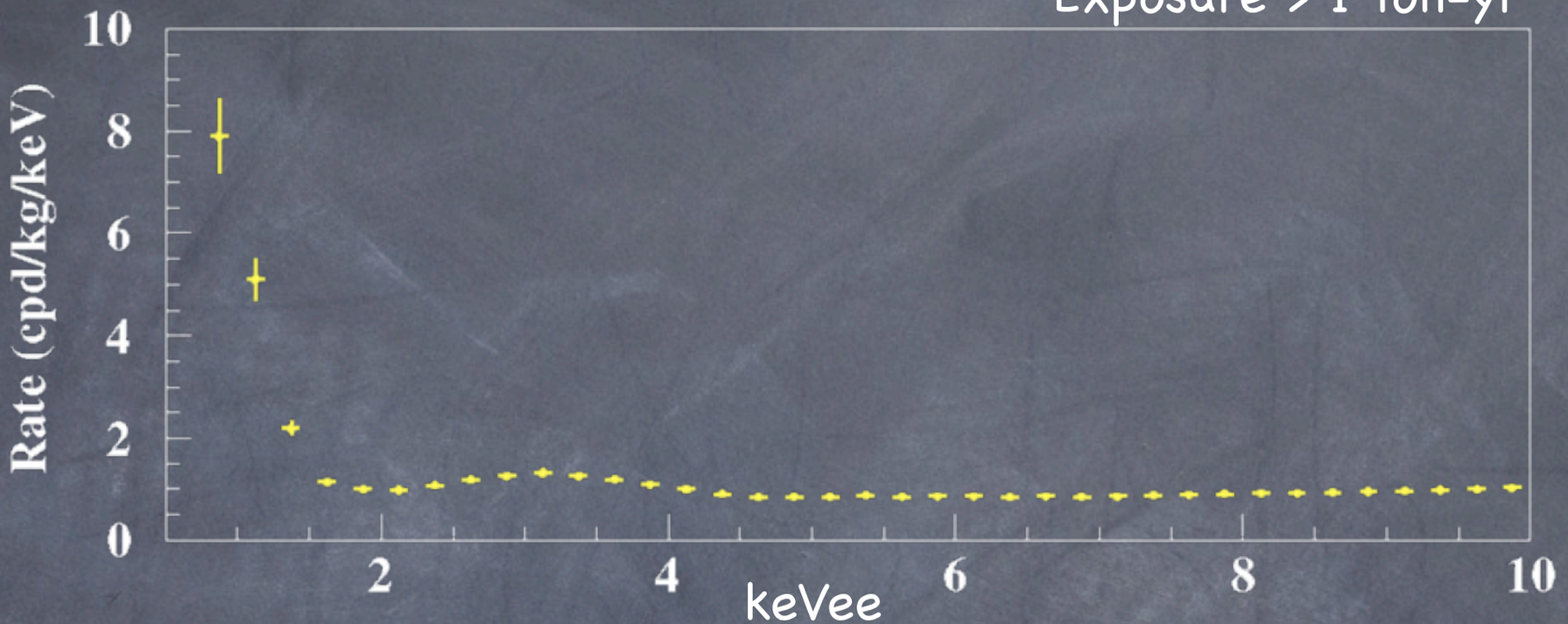
Annual modulation



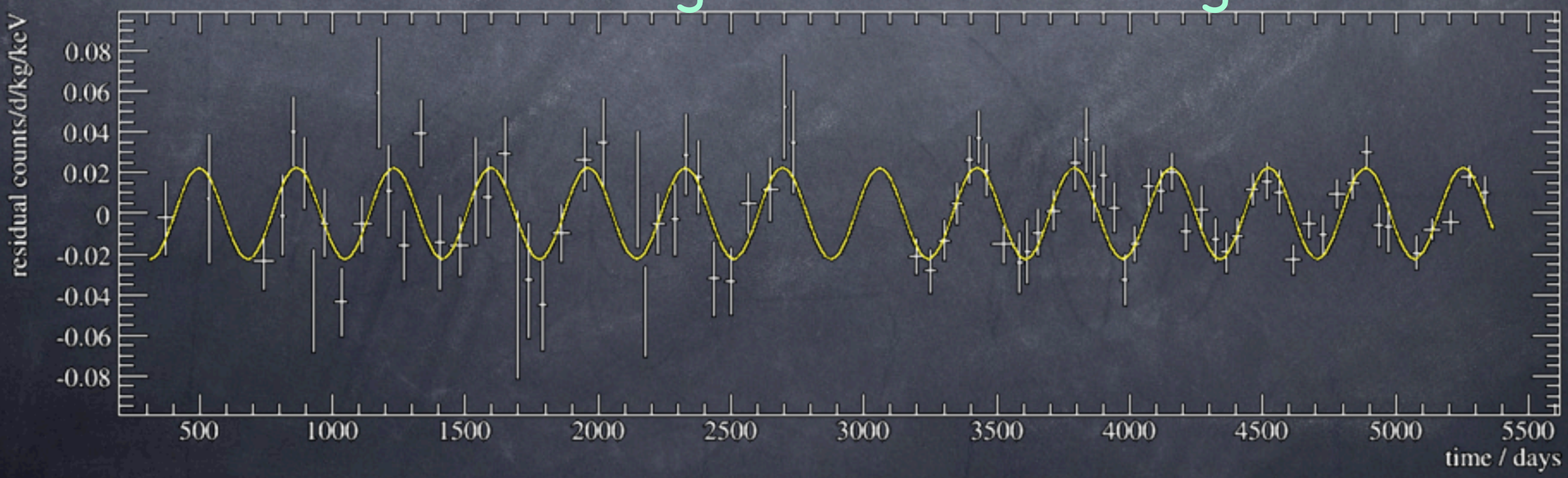
Max on June 2, min on Dec 2 phase = 152 days

DAMA/LIBRA

Exposure > 1 ton-yr

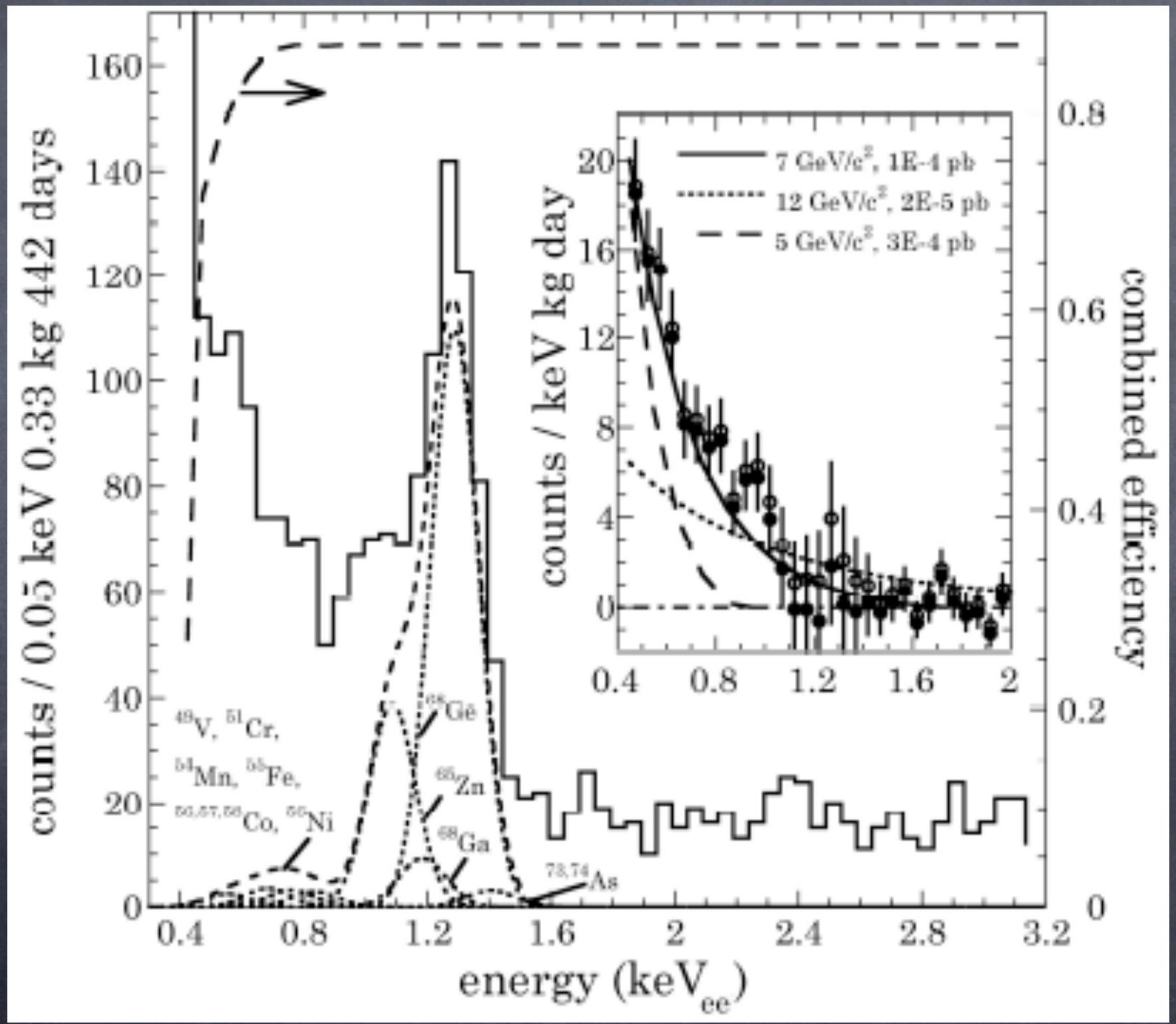


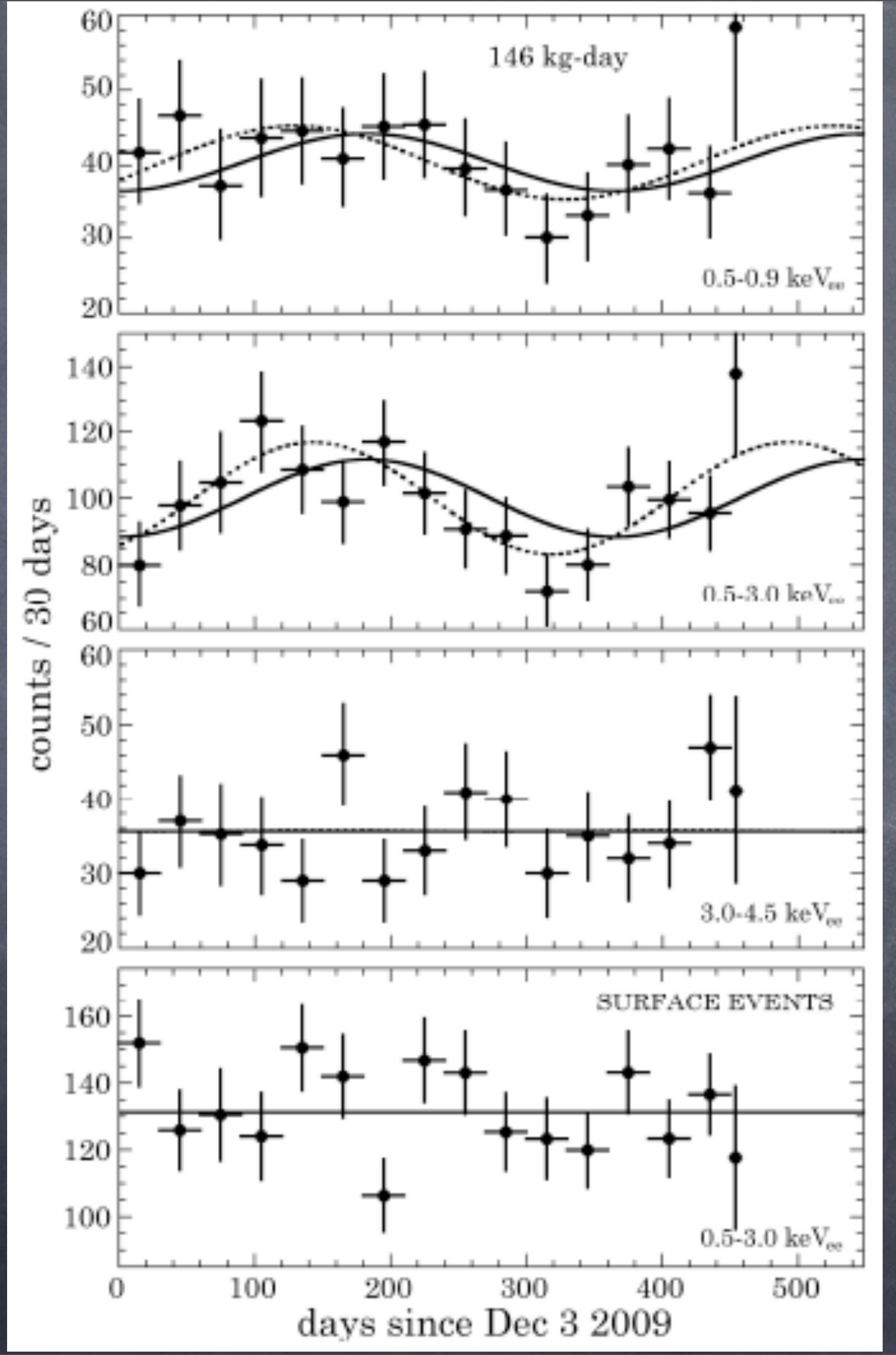
Modulation signal at almost 9 sigma



CoGeNT

Exposure = 146 kg-day




146 kg-day
0.5-0.9 keV$_{ee}$
0.5-3.0 keV$_{ee}$
3.0-4.5 keV$_{ee}$
SURFACE EVENTS
0.5-3.0 keV$_{ee}$
counts / 30 days
days since Dec 3 2009

2.8 sigma

Modulations?

- In the energy bins 0.5-0.9 keVee, 0.9-3 keVee and 3-4.5 keVee, the goodness-of-fit for no modulations is acceptable
- 1.9 sigma evidence for modulations in the first bin
- 3 sigma evidence in the second bin... but the fitted phase is 2 sigma too low from the expectation
- No modulations in the third bin

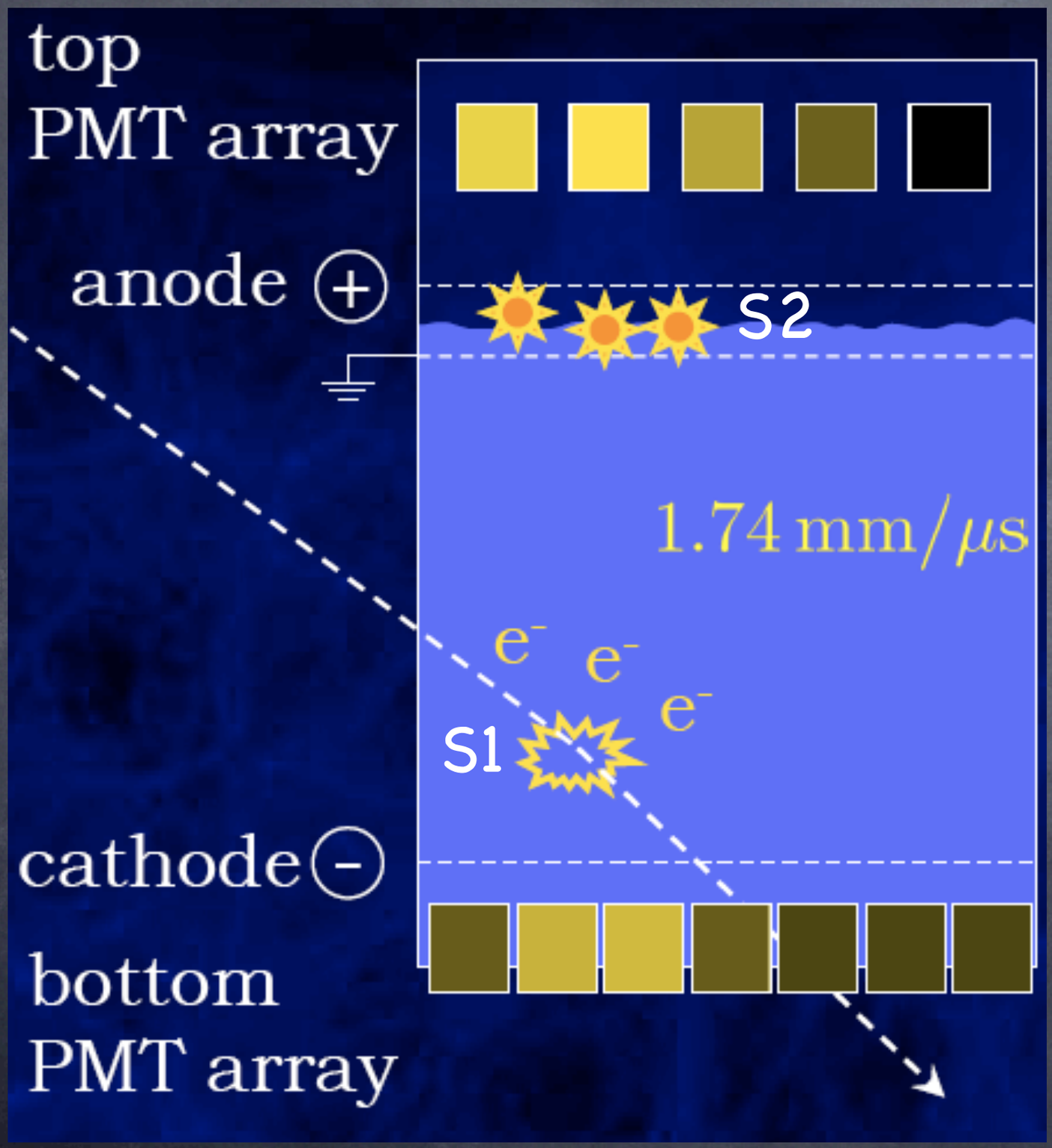
Inconsistent picture:

- Insignificant modulation in the first bin is in conflict with expectation from the energy spectrum
- Using DM for the spectrum, modulation in the second bin is reduced significantly and is only slightly preferred over no modulations
- i.e., modulation is not explained in the region where the signal is strongest
- DM favored by modulation signal is excluded by the unmodulated rate
- Need to simultaneously explain excess in unmodulated rate below 0.9 keVee and significant modulation above

CRESST

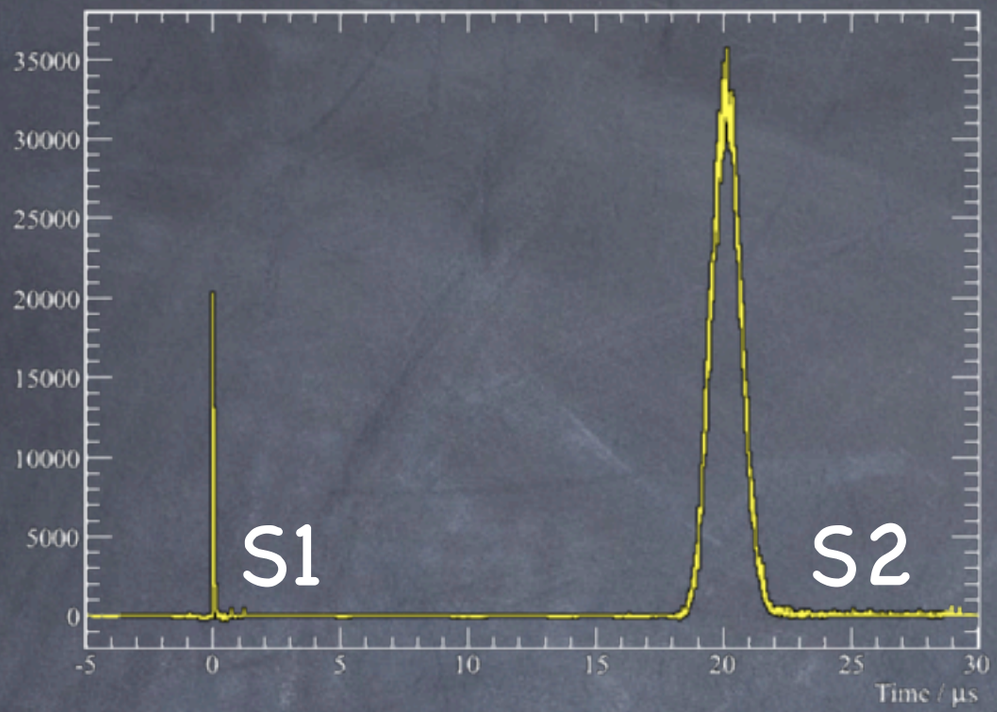
- 9 $CaWO_4$ crystals
- Several targets in single detector
- 400 kg-day exposure
- No excess in Ca and W bands
- 32 events in O band. Expected bkg is 9

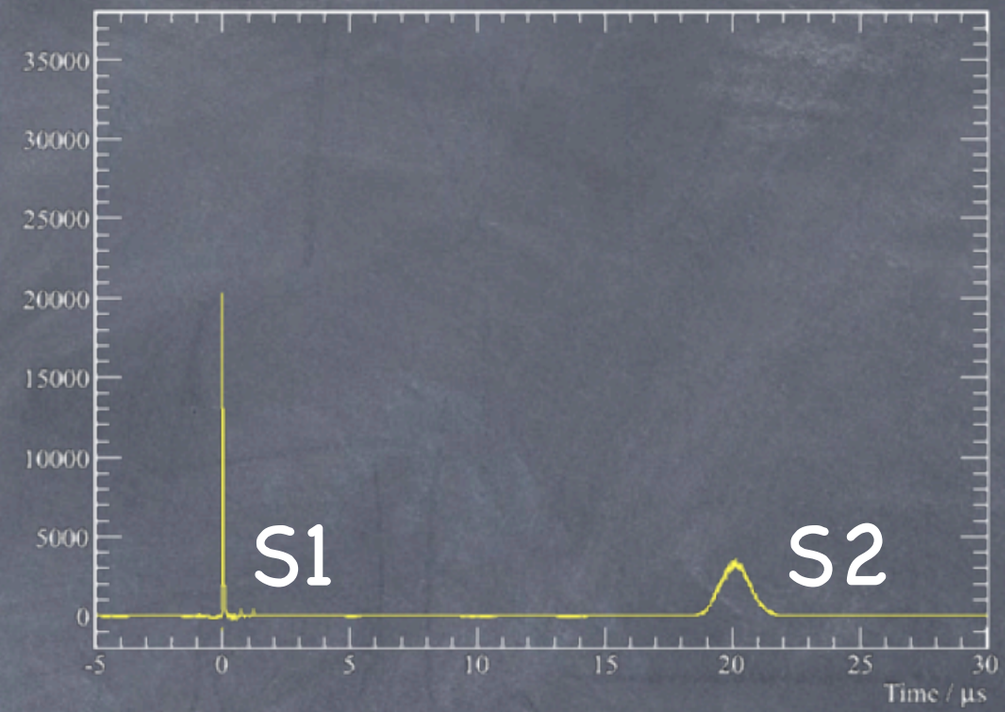
XENON



S1: prompt scintillation

S2: secondary scintillation

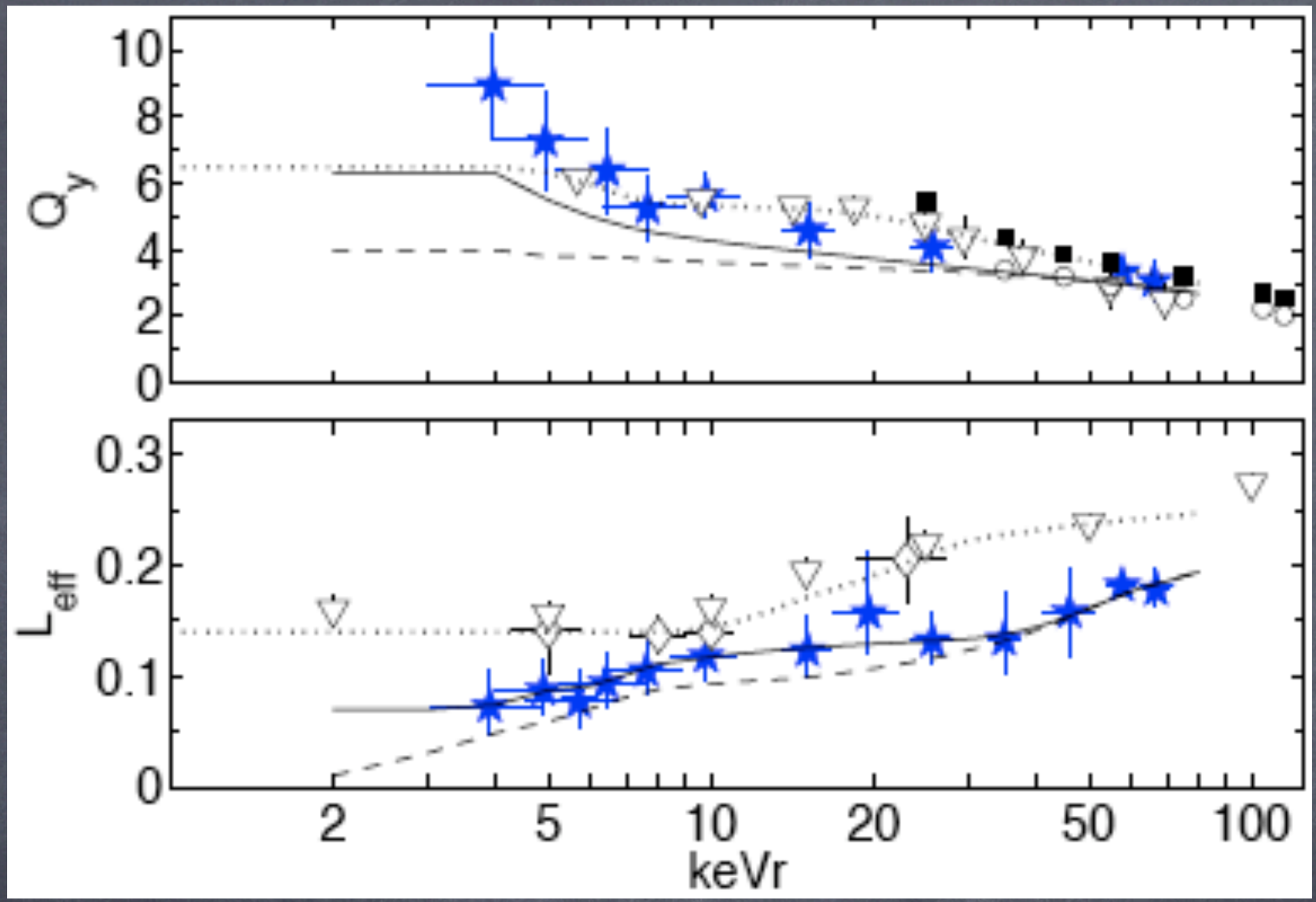




Electronic recoil

Nuclear recoil

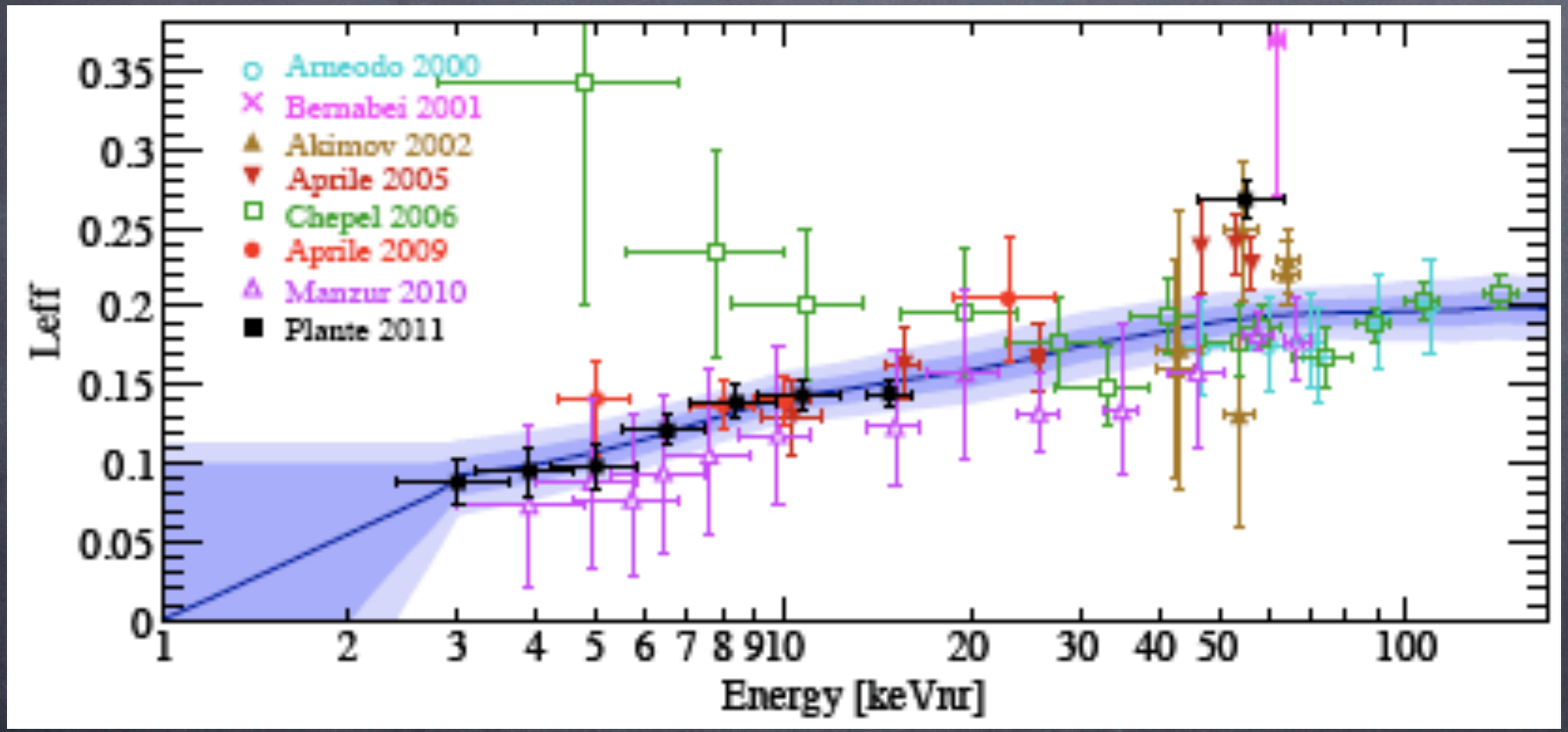
$$\left(\frac{\mathrm{S2}}{\mathrm{S1}}\right)_{\mathrm{n},\chi} \ll \left(\frac{\mathrm{S2}}{\mathrm{S1}}\right)_{\mathrm{e},\gamma}$$

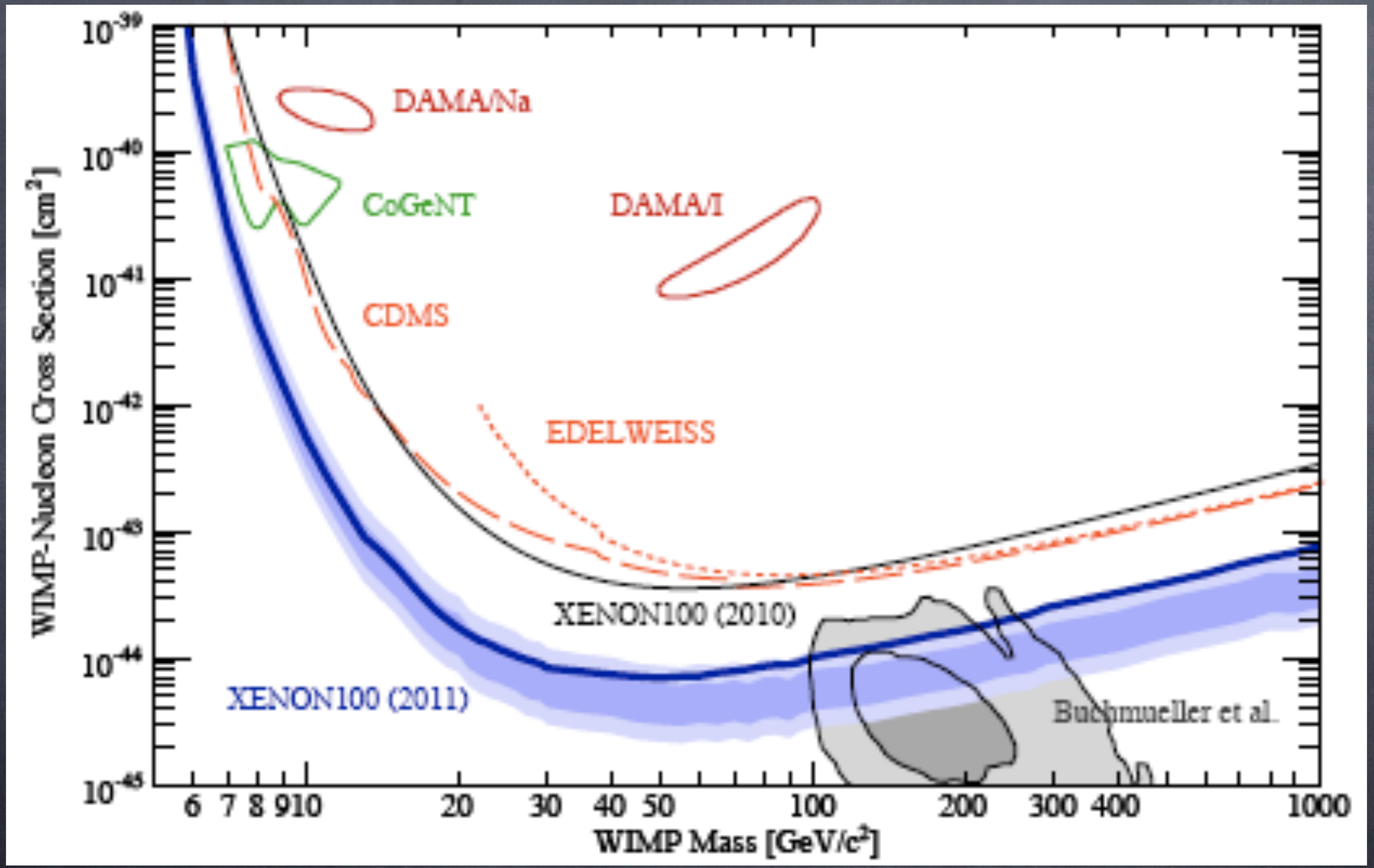


$$\frac{S2}{S1} \propto \frac{Q_y}{L_{eff}}$$

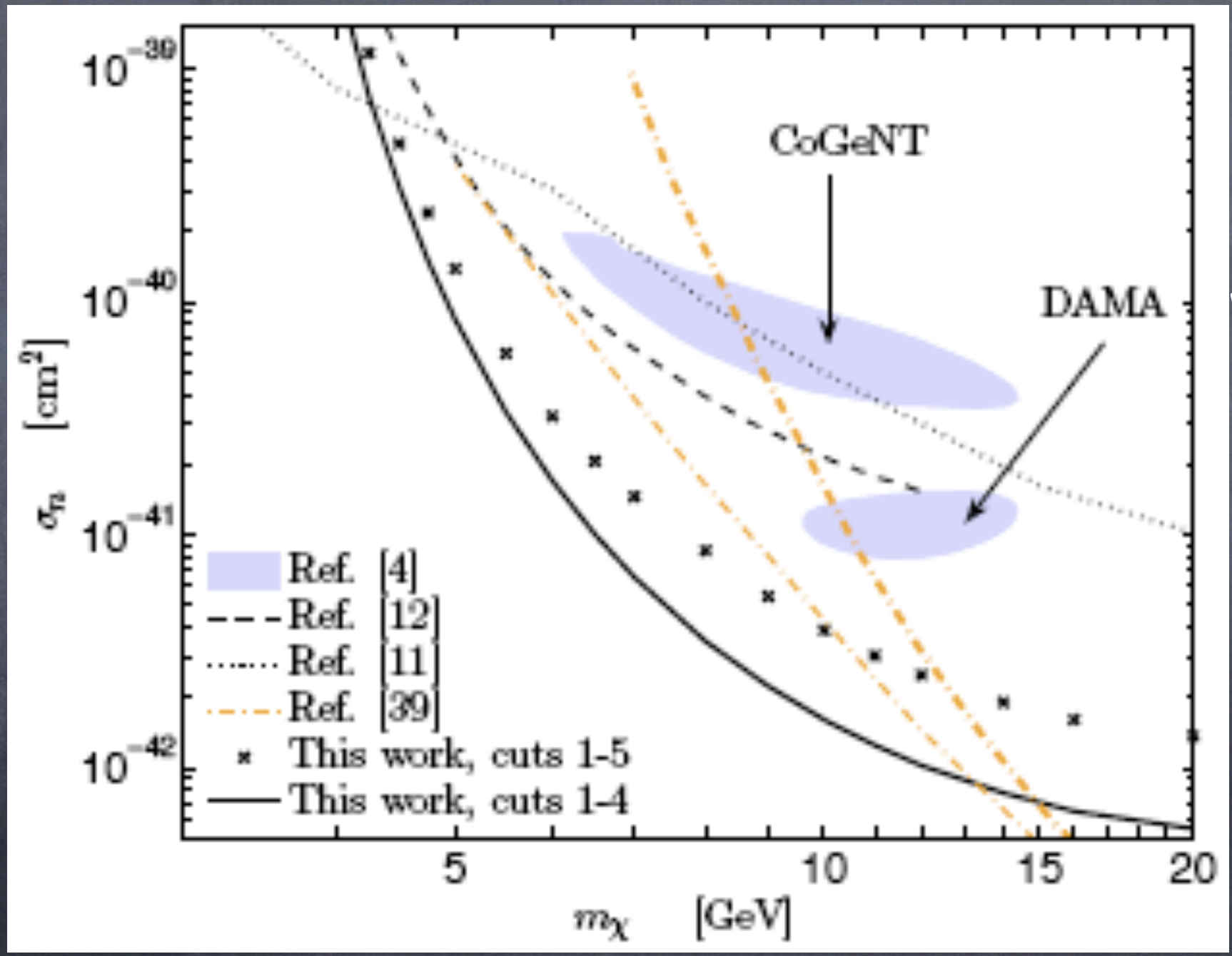
(# of detected e- per keV)

(scintillation efficiency)


Ameodo 2000
Bernabei 2001
Akimov 2002
Aprile 2005
Chepel 2006
Aprile 2009
Manzur 2010
Plante 2011
Leff
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
20
30
40
50
100
Energy [keVnr]

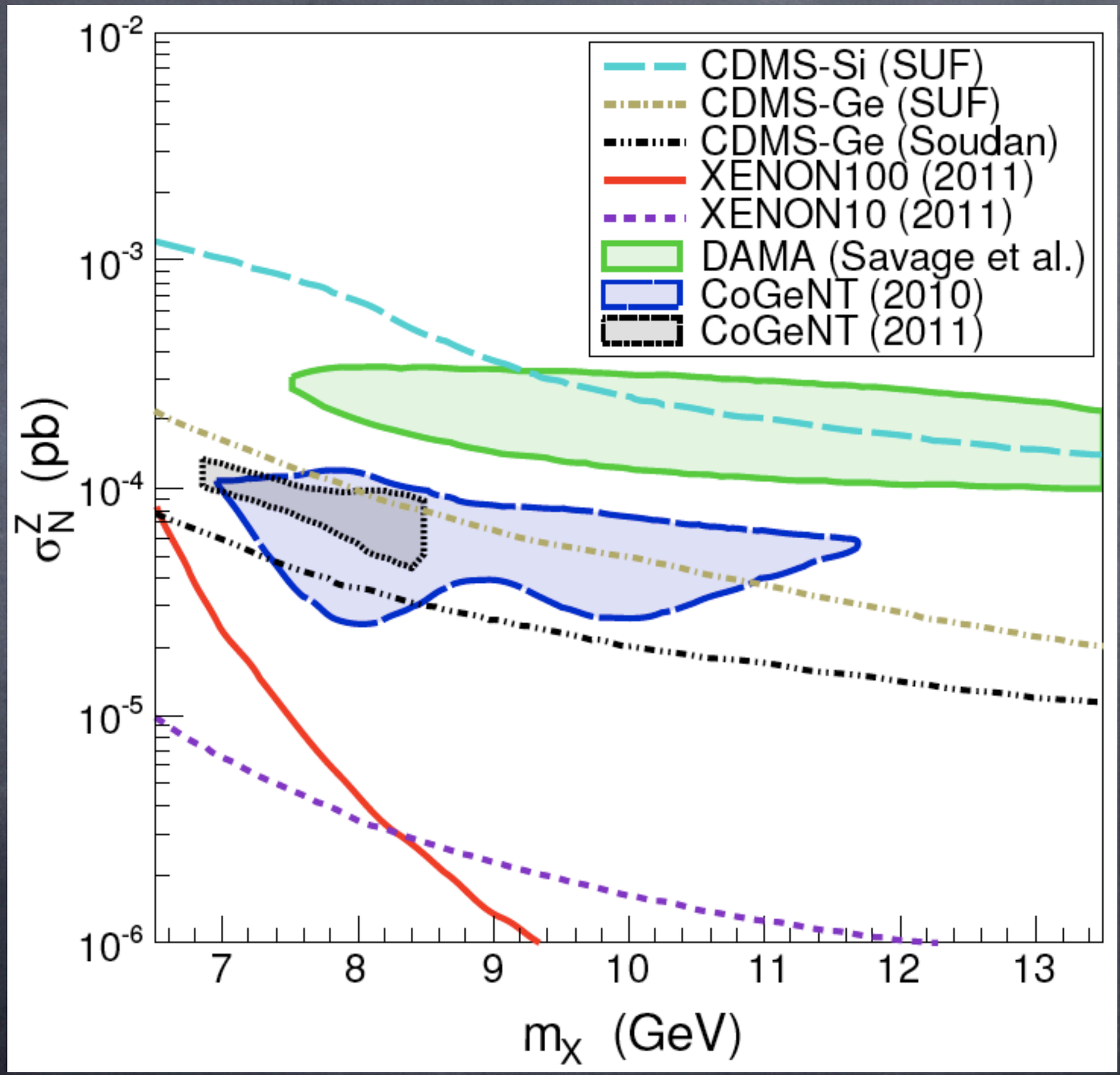

DAMA/Na
CoGeNT
DAMA/I
CDMS
EDELWEISS
XENON100 (2010)
XENON100 (2011)
Buchmueller et al.
WIMP-Nucleon Cross Section [cm²]
WIMP Mass [GeV/c²]
10⁻³⁹
10⁻⁴⁰
10⁻⁴¹
10⁻⁴²
10⁻⁴³
10⁻⁴⁴
10⁻⁴⁵
6 7 8 9 10 20 30 40 50 100 200 300 400 1000

XENON10 bound using only S2 data



with channeling

$$f_n/f_p = 1$$


CDMS-Si (SUF)
CDMS-Ge (SUF)
CDMS-Ge (Soudan)
XENON100 (2011)
XENON10 (2011)
DAMA (Savage et al.)
CoGeNT (2010)
CoGeNT (2011)
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
σ^{SI}_N (pb)
7
8
9
10
11
12
13
m_X (GeV)

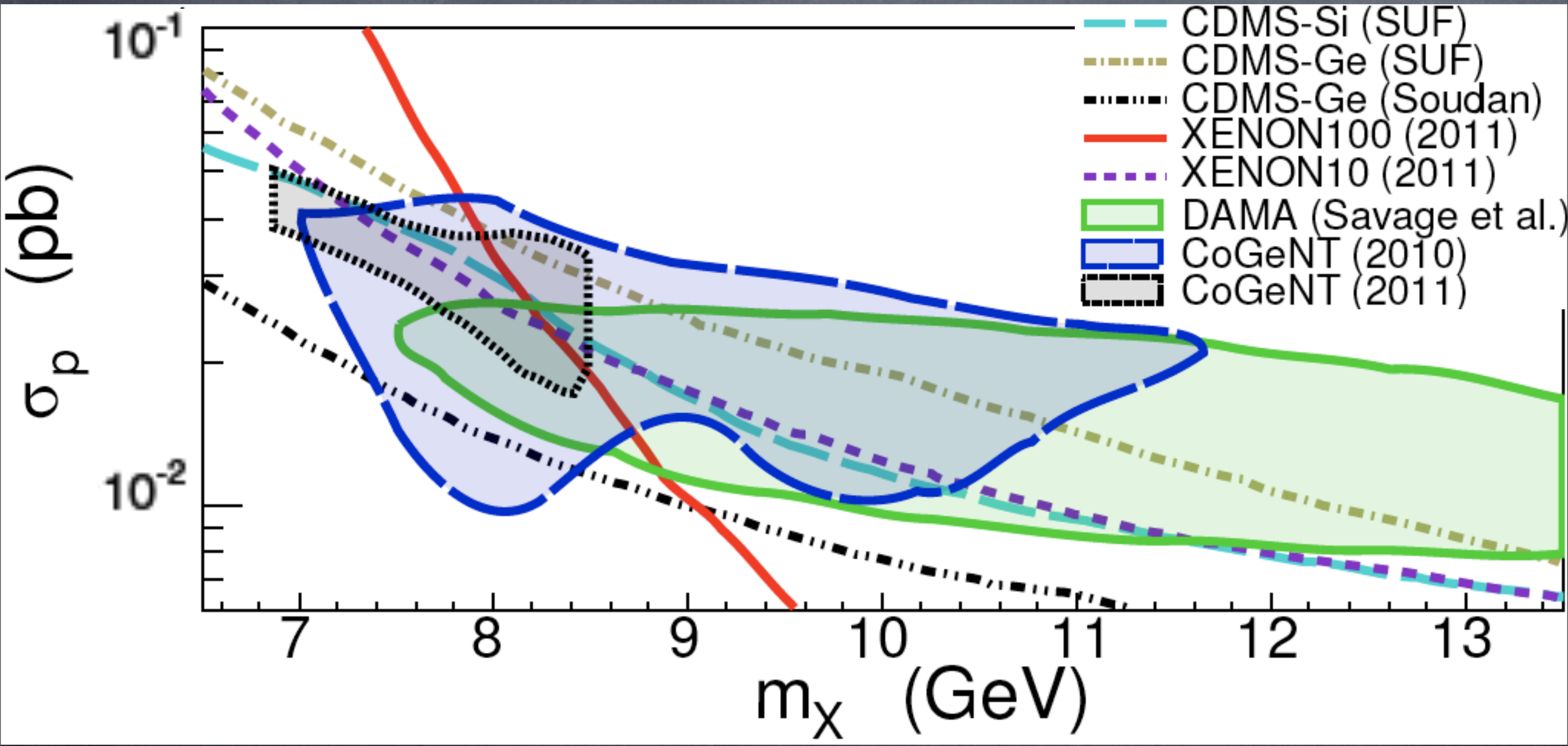
Is it possible to reconcile DAMA with CoGeNT and evade XENON bounds?

Isotopes of Xe (Z=54)

A	128	129	130	131	132	134	136
Abundance (%) $[\eta_i]$	1.9	26.4	4.1	21.2	26.9	10.4	8.9
$\sigma_A = 0$ at $f_n/f_p =$	-0.73	-0.72	-0.71	-0.70	-0.69	-0.675	-0.66

Cannot have complete destructive interference for more than one isotope

$$f_n / f_p = -0.7$$



Scattering on Na is enhanced compared to Ge

Can XENON exclude the IVDM explanation?

Element	Xe	Ge	Si	Ca	W	Ne	C
Xe (54,*)	1.00	8.79	149.55	138.21	10.91	34.31	387.66
Ge (32,*)	22.43	1.00	68.35	63.14	130.45	15.53	176.47
Si (14,*)	172.27	30.77	1.00	1.06	757.44	1.06	2.67
Ca (20,*)	173.60	31.53	1.17	1.00	782.49	1.10	2.81
W (74,*)	2.98	13.88	177.46	166.15	1.00	41.64	466.75
Ne (10,*)	163.65	28.91	4.39	4.09	726.09	1.00	11.52
C (6,*)	176.35	32.13	1.07	1.02	789.59	1.12	1.00
I (53,127)	1.94	5.51	127.04	118.35	20.68	28.92	326.95
Cs (55,133)	1.16	7.15	139.65	127.61	12.32	31.88	355.27
O (8,16)	178.49	32.13	1.08	1.03	789.90	1.13	1.01
Na (11,23)	101.68	13.77	8.45	8.33	481.03	2.27	22.68
Ar (18,36)	178.49	32.13	1.08	1.03	789.90	1.13	1.01
F (9,19)	89.39	10.88	12.44	11.90	425.93	3.05	33.47

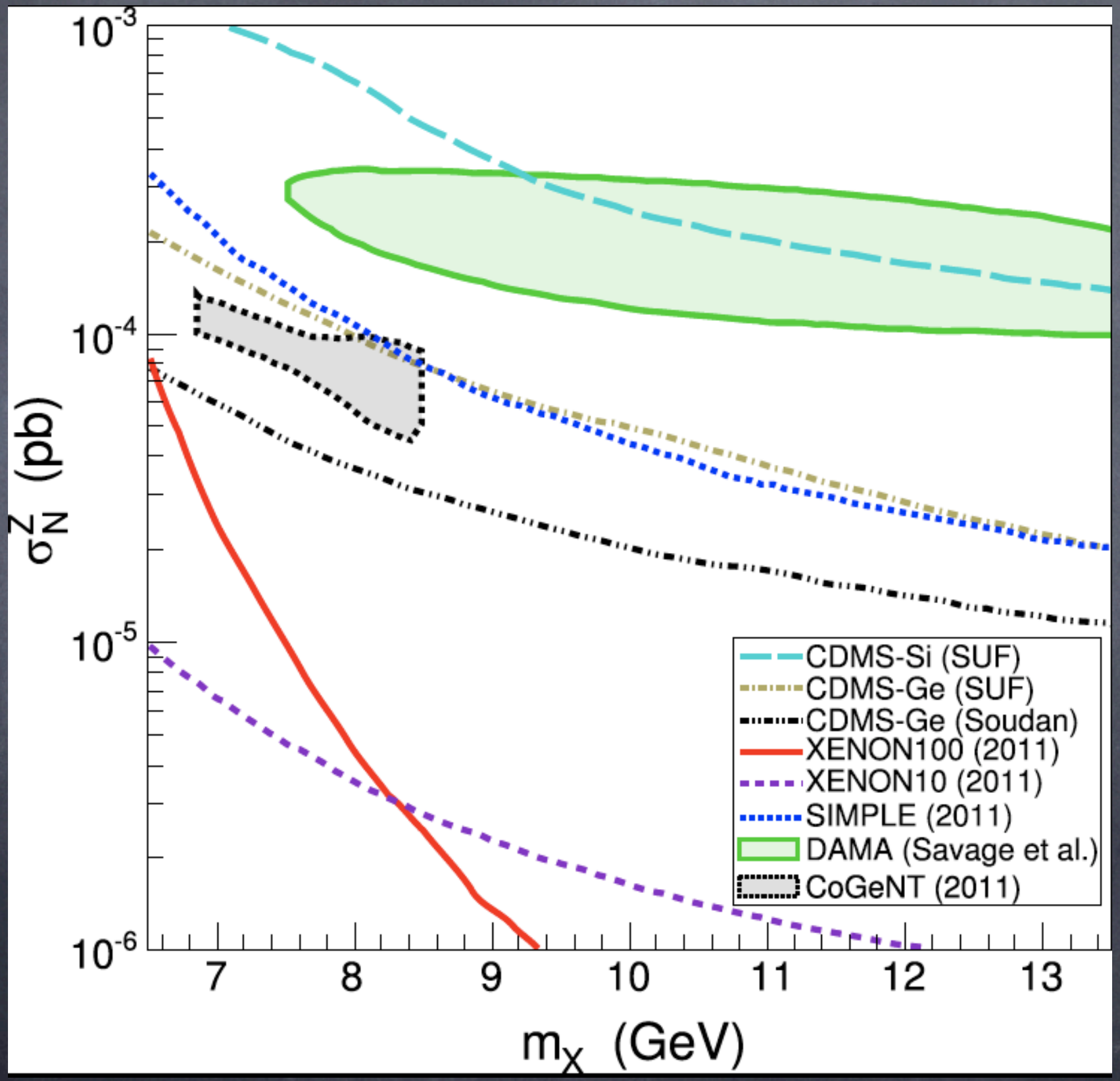
XENON has to exclude CoGeNT by a factor of 22.43

XENON has to exclude DAMA by a factor of 101.68

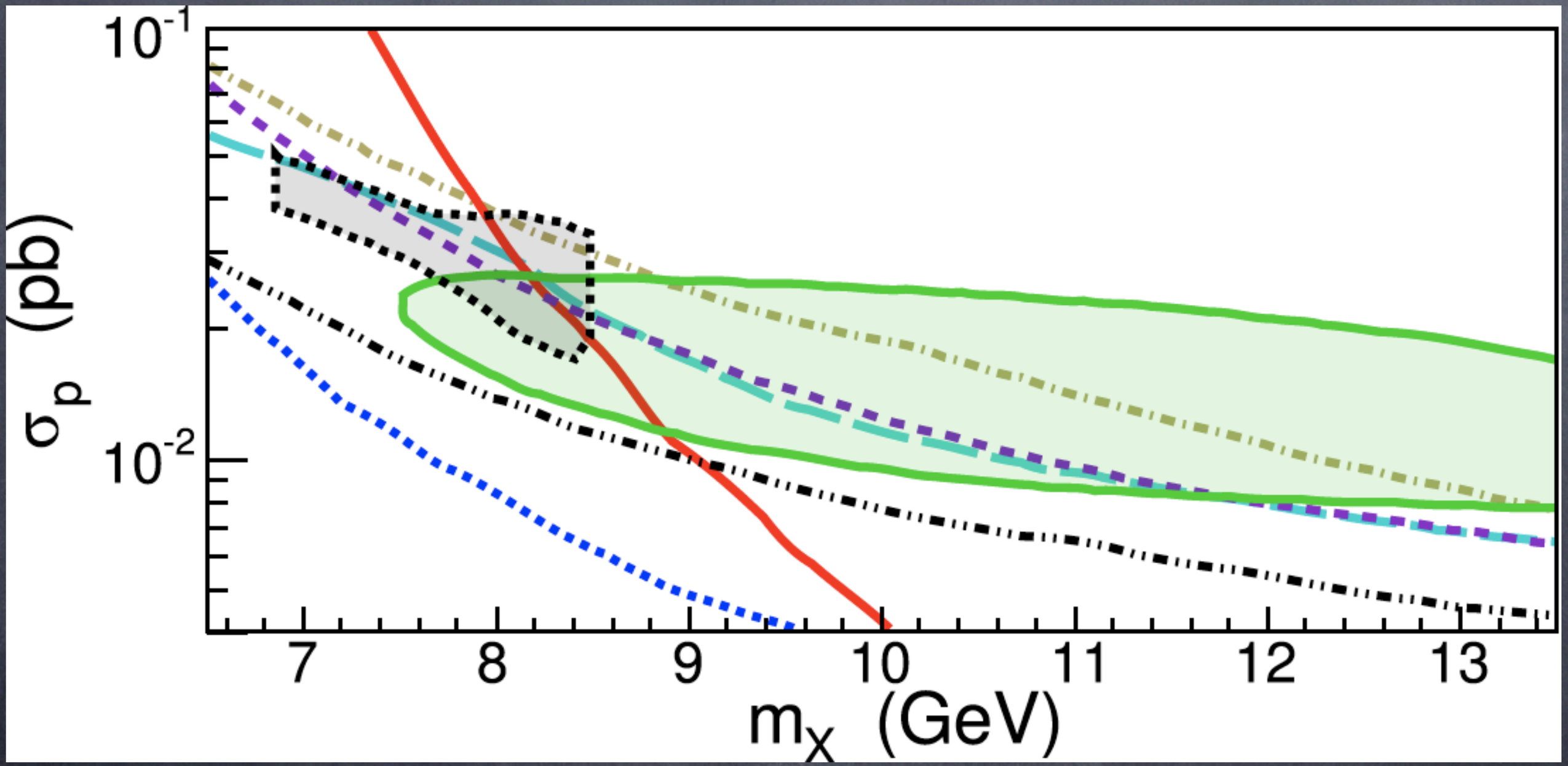
Predictions?

- CRESST oxygen: $\sigma_N^{Z=8} \simeq 8.5\sigma_N^{Z=32}$
- COUPP carbon: $\sigma_N^{Z=6} \simeq 8.4\sigma_N^{Z=32}$
- COUPP fluorine: $\sigma_N^{Z=9} \simeq 4.2\sigma_N^{Z=32}$

New bound from SIMPLE (C_2ClF_5)



SIMPLE problem for $f_n/f_p = -0.7$



Scattering on Cl and F is enhanced compared to Ge!

Conclusions

- IVDM can reconcile CoGeNT and DAMA and evade bounds from XENON100
- For this explanation to be viable CDMS-Ge and SIMPLE need to be wrong
- It is possible that DAMA or CoGeNT or both are not seeing DM
- Independently of DAMA/CoGeNT it is clear that the assumption of isospin-conservation has far-reaching consequences and should be relaxed in DM studies