Aspects of IVDM

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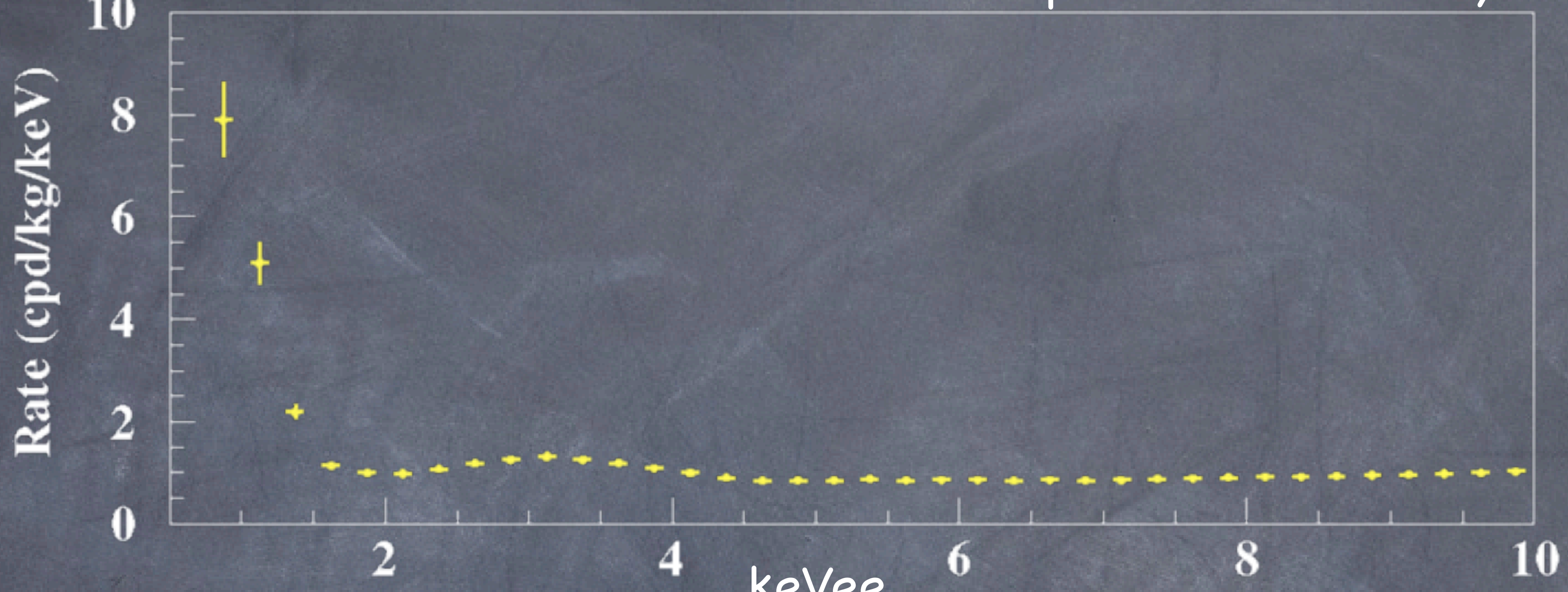
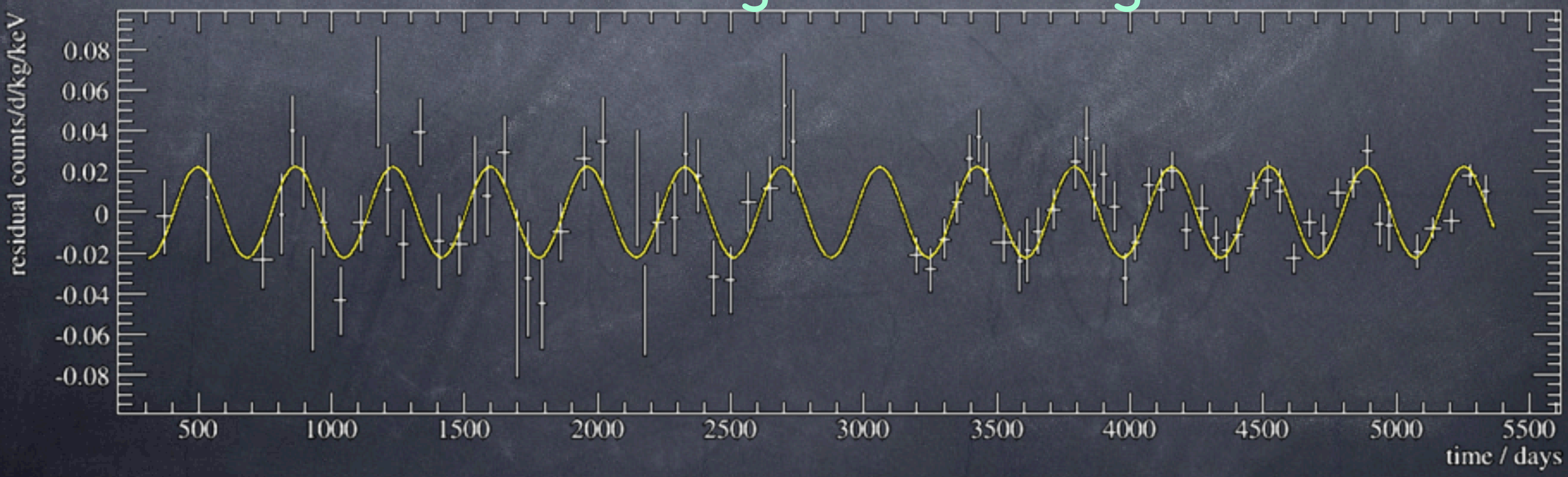
Scattering cross section

- 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 $f_n/f_p = \dfrac{-Z}{A-Z}, \quad \sigma_A = 0!$

DAMA/LIBRA

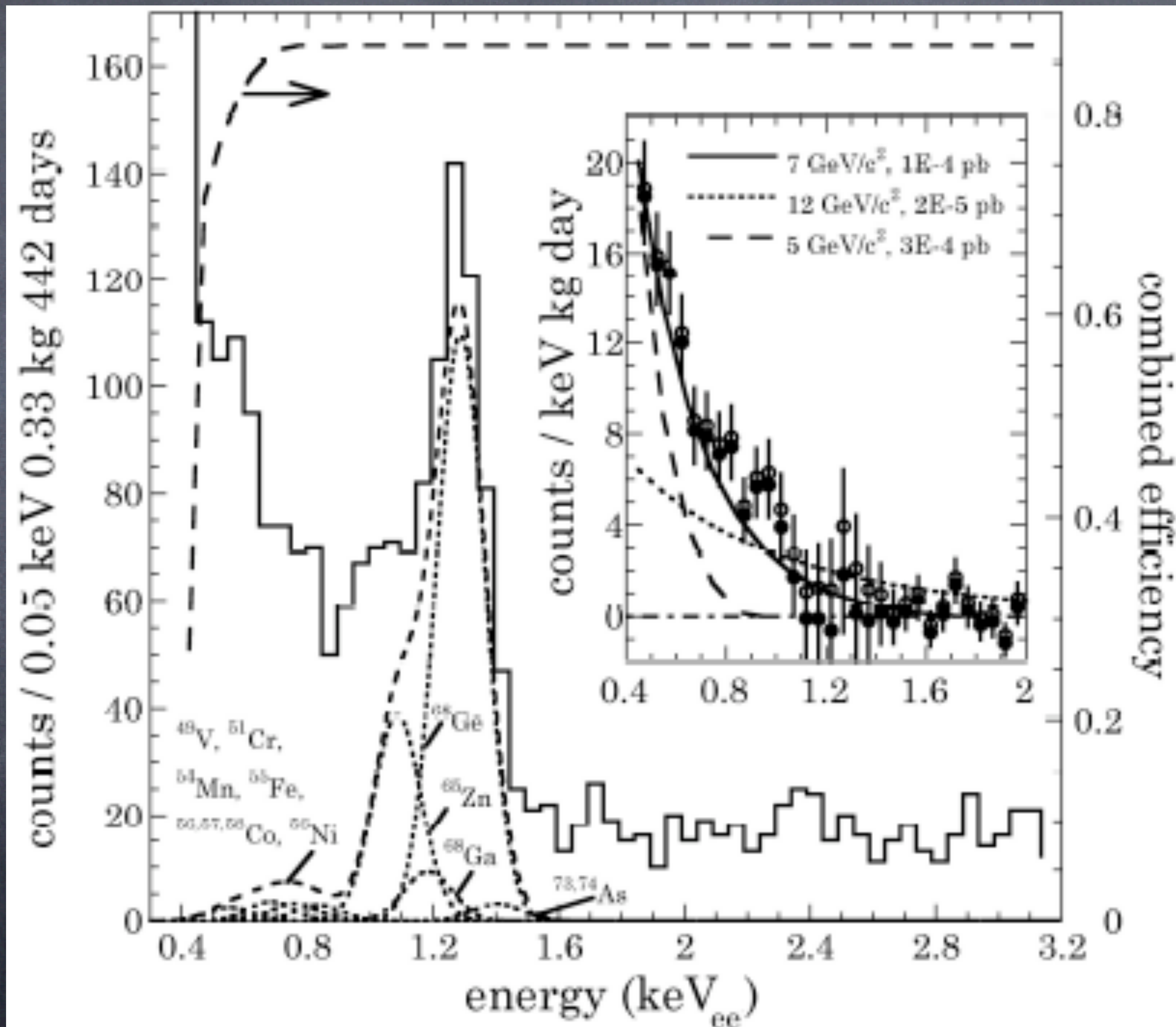


Modulation signal at 8.9 sigma



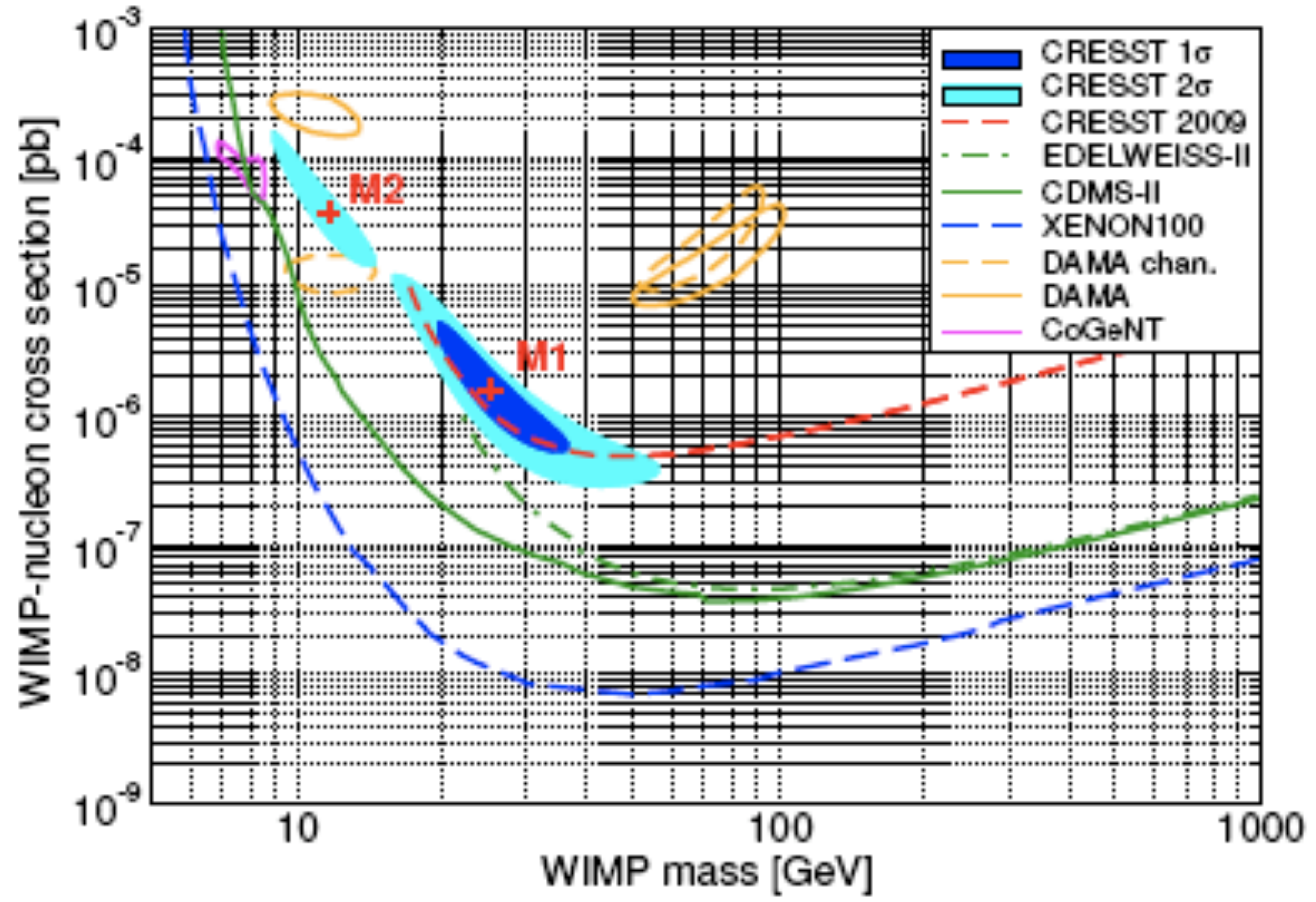
CoGeNT

Exposure = 146 kg-day



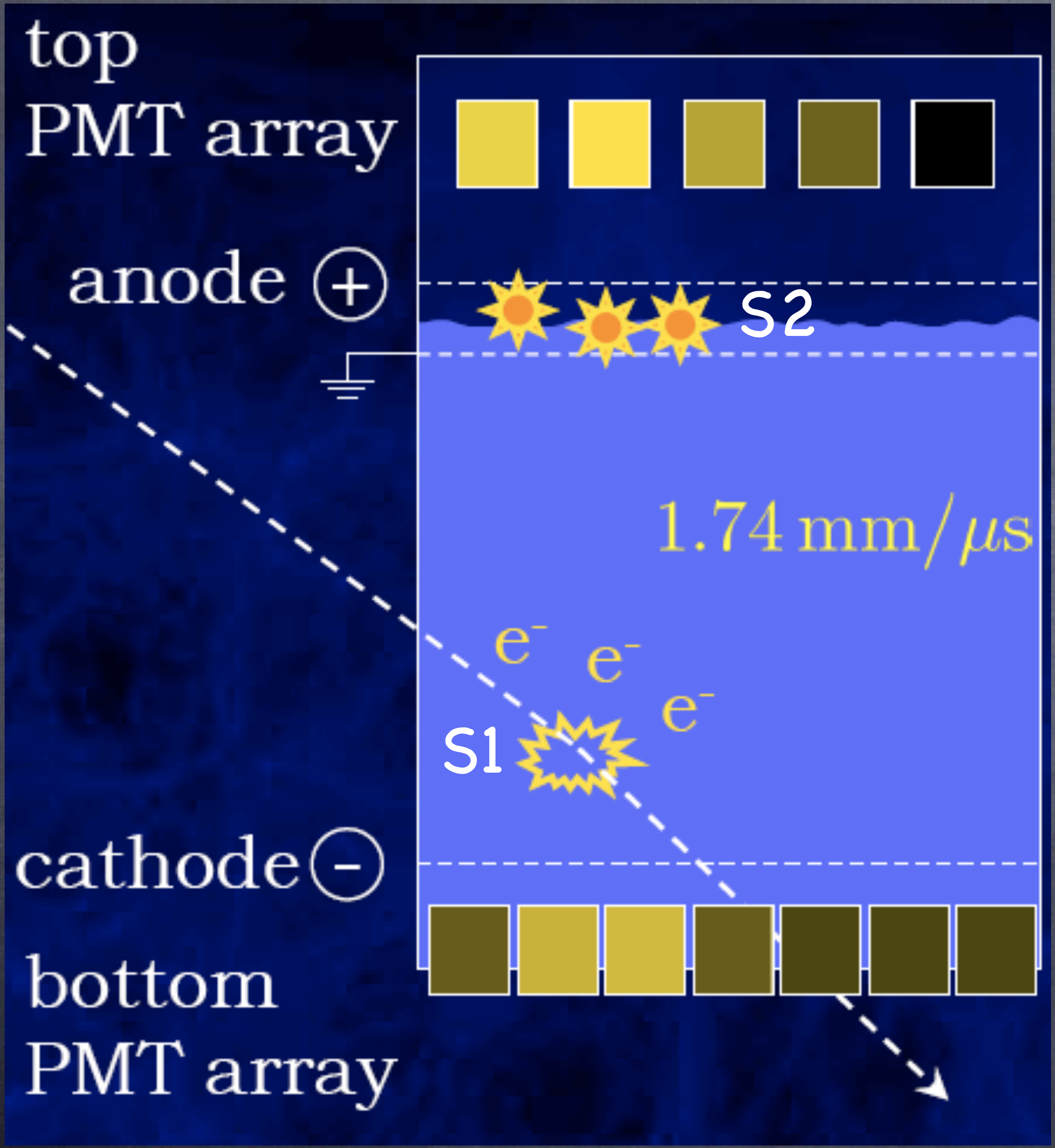
CRESST

- 8 CaWO_4 crystals
- Several targets in single detector
- 730 kg-day exposure
- 67 events. Expected bkg is 29
- 2 possibilities: recoils on W/Ca (0.69/0.25) or O/Ca (0.52/0.48)



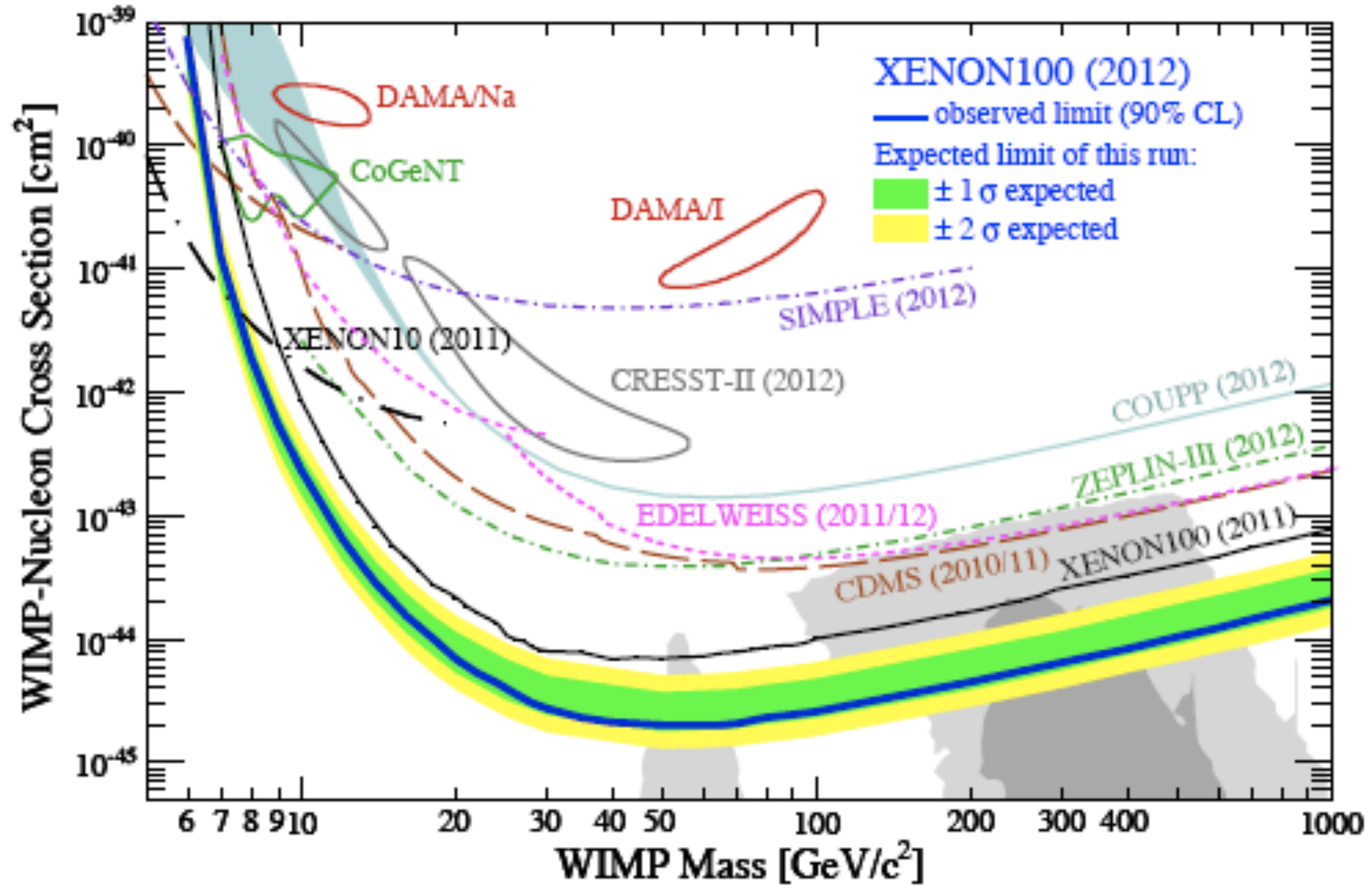
WIMP-nucleon cross section [pb]
WIMP mass [GeV]
CRESST 1σ
CRESST 2σ
CRESST 2009
EDELWEISS-II
CDMS-II
XENON100
DAMA chan.
DAMA
CoGeNT
M1
M2

XENON

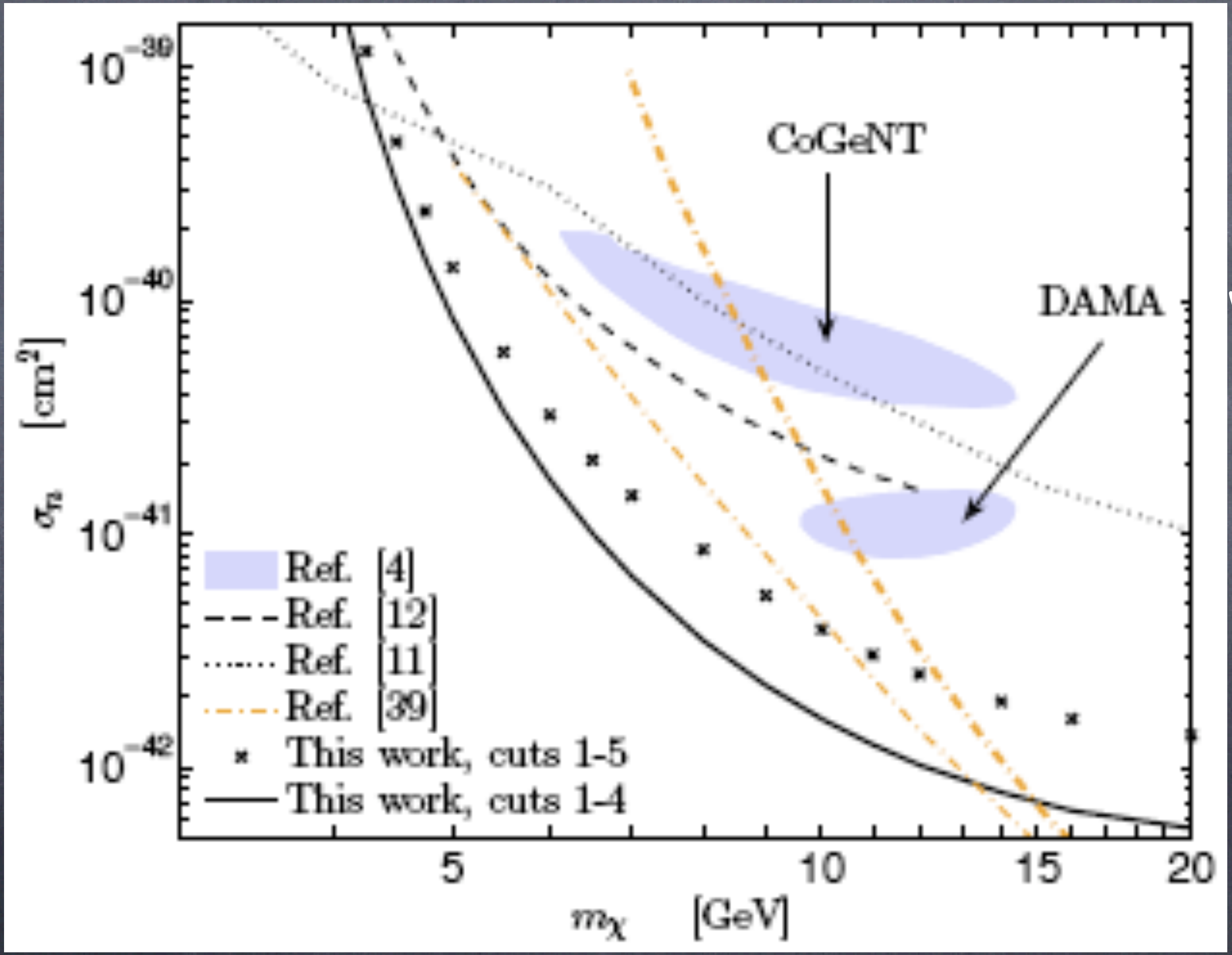


S1: prompt scintillation

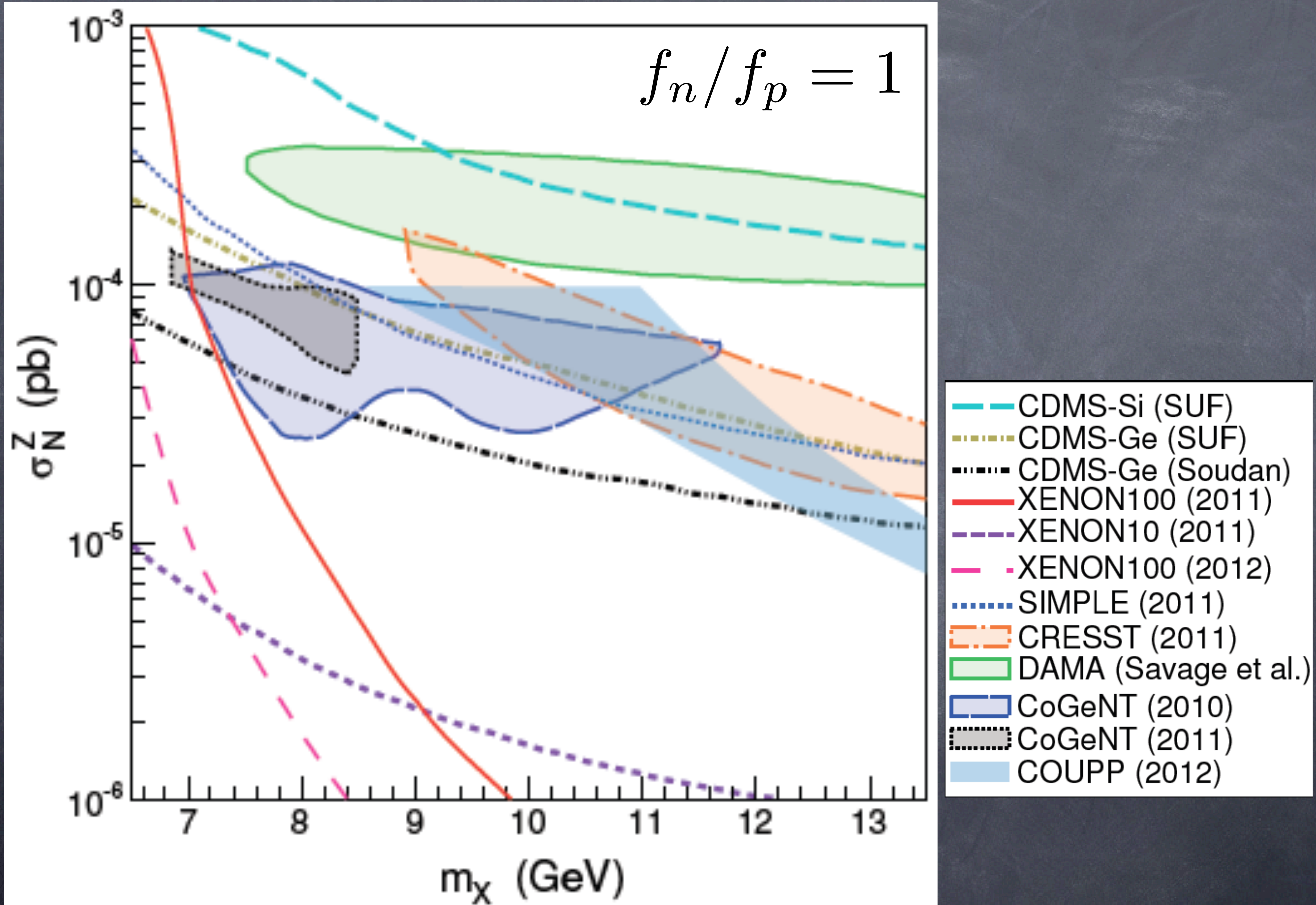
S2: secondary scintillation


XENON100 (2012)
observed limit (90% CL)
Expected limit of this run:
± 1 σ expected
± 2 σ expected
DAMA/Na
CoGeNT
DAMA/I
SIMPLE (2012)
XENON10 (2011)
CRESST-II (2012)
COUPP (2012)
ZEPLIN-III (2012)
EDELWEISS (2011/12)
CDMS (2010/11)
XENON100 (2011)
WIMP-Nucleon Cross Section [cm^2]
WIMP Mass [GeV/c^2]
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



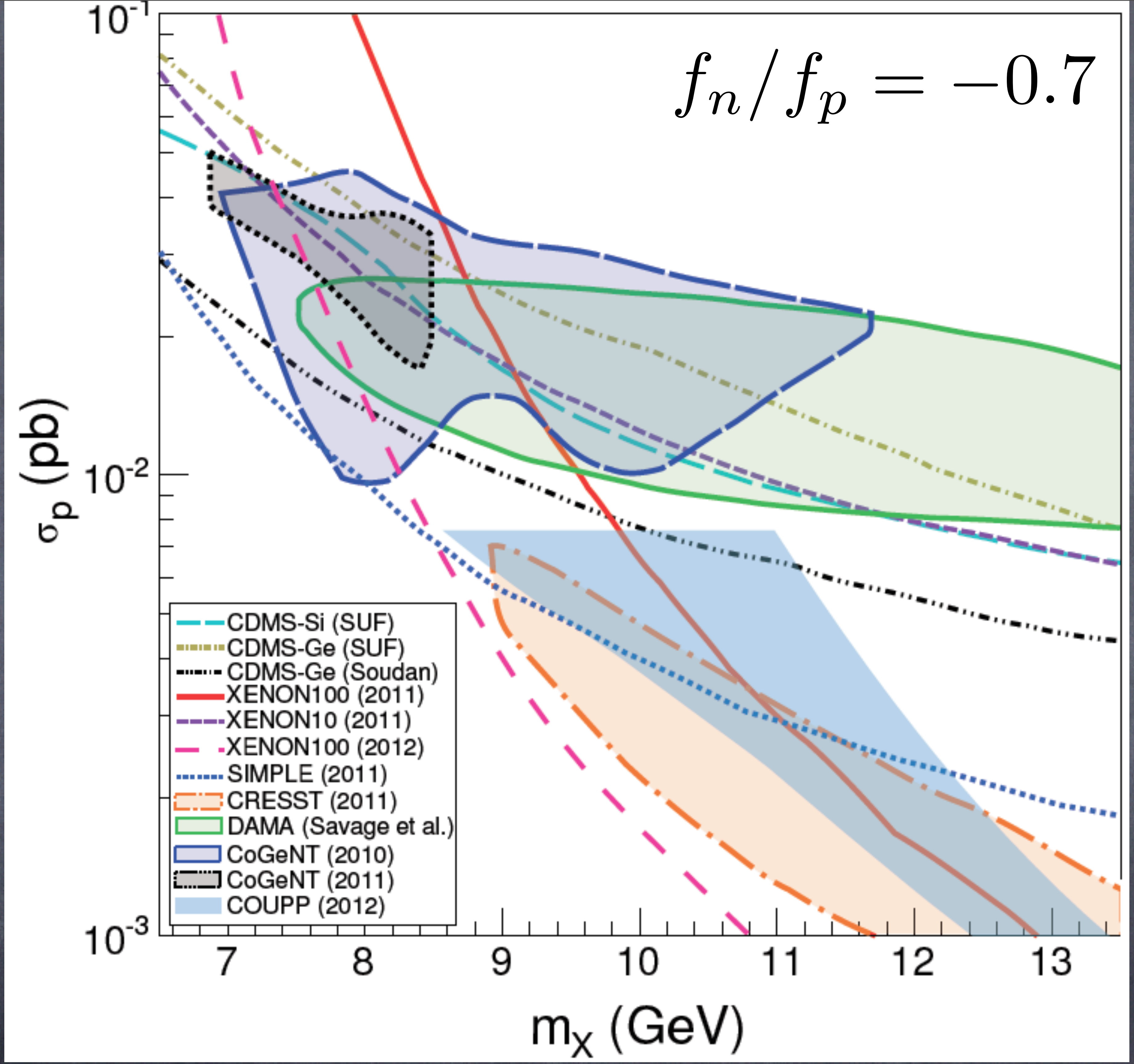
Note bound from SIMPLE (C_2ClF_5)

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 (%) [η_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



DAMA: scattering on Na is suppressed less than on Ge

CRESST: scattering on Ca/O is suppressed less than on Ge

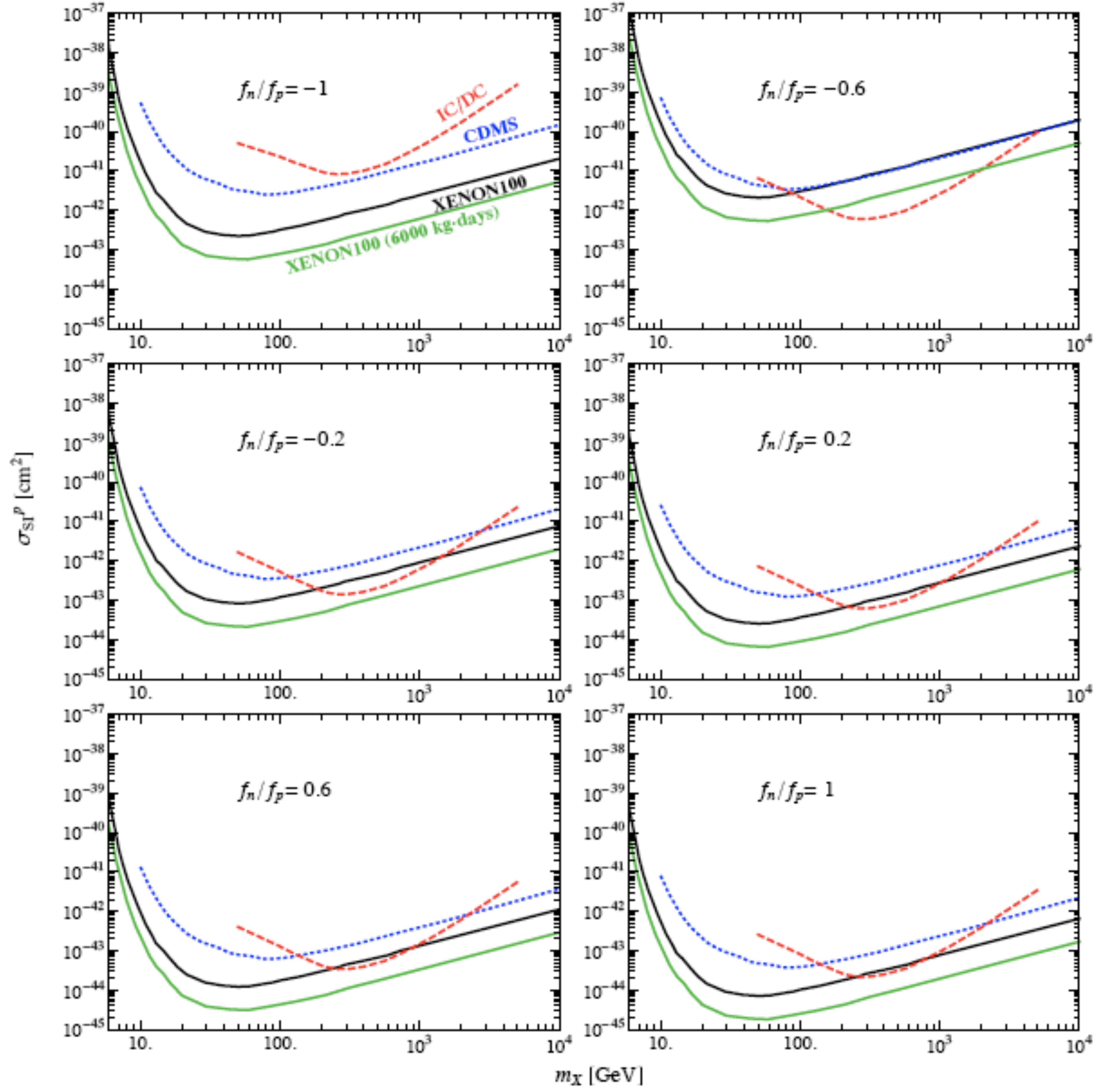
SIMPLE: scattering on Cl/F is suppressed less than on Ge!

Conclusions so far...

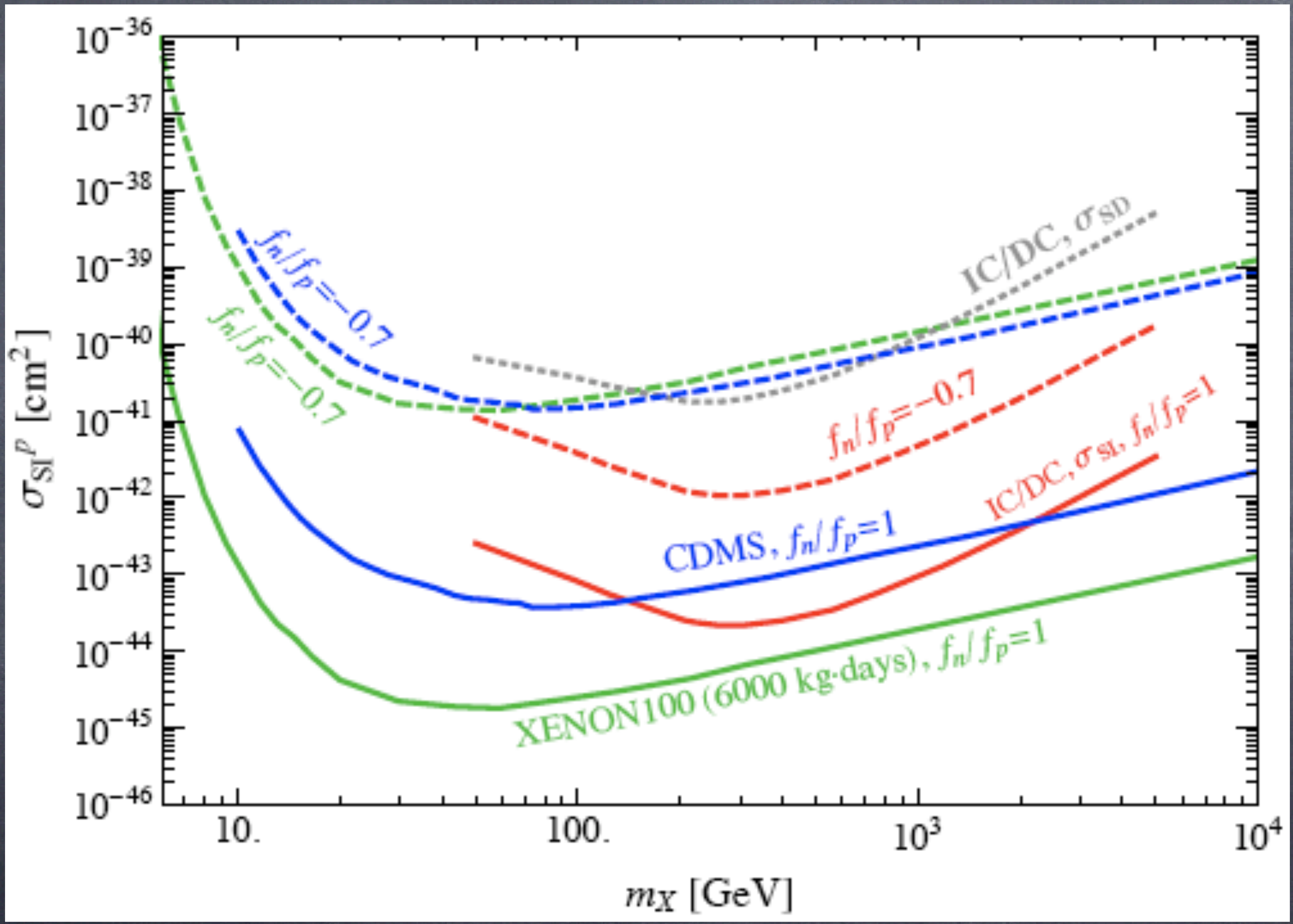
- IVDM can reconcile CoGeNT and DAMA (and perhaps even CRESST) and marginally evade bounds from XENON
- For this explanation to be viable SIMPLE and the low-threshold CDMS-Ge analysis need to be wrong
- It is possible that DAMA or CoGeNT or CRESST or none of them are seeing DM
- Independently of DAMA/CoGeNT/CRESST it is clear that the assumption of isospin-conservation has far-reaching consequences and should be relaxed in DM studies

IVDM in the Sun

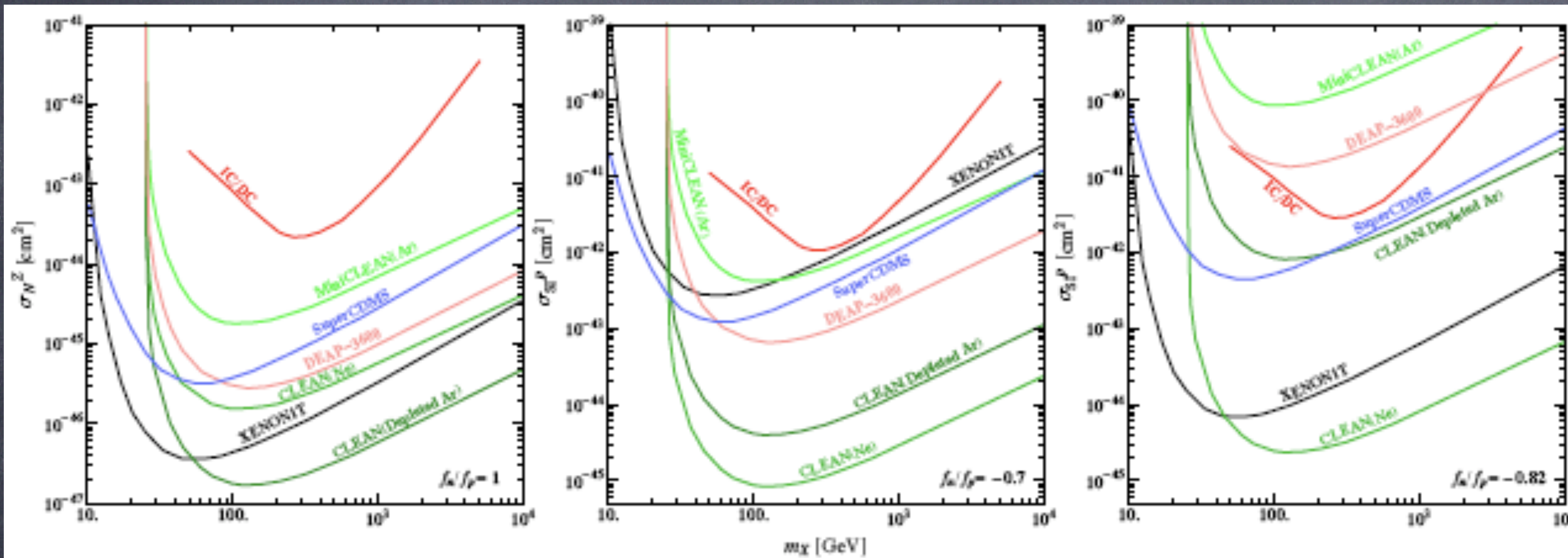
- DD experiments with high-A materials can suffer great losses of sensitivity
- In the Sun, a significant fraction of DM captures arise from scattering of low-A nuclei which have a small neutron fraction
- So, effects of destructive interference from isospin-violation are not as drastic i.e., neutrino detectors like IceCube/DeepCore should exhibit less suppressed sensitivity
- On the other hand, need hard annihilation channels to produce detectable neutrinos



IC/DC may be competitive even for SI scattering



10^{-36}
10^{-37}
10^{-38}
10^{-39}
10^{-40}
10^{-41}
10^{-42}
10^{-43}
10^{-44}
10^{-45}
10^{-46}
$\sigma_{SI}{}^{p}$ [cm^2]
10.
100.
10^3
10^4
m_X [GeV]
$f_n/f_p=-0.7$
$f_n/f_p=-0.7$
IC/DC, σ_{SD}
$f_n/f_p=-0.7$
IC/DC, σ_{SI}, $f_n/f_p=1$
CDMS, $f_n/f_p=1$
XENON100 (6000 kg·days), $f_n/f_p=1$



σ_N^Z [cm^2]
IC/DC
MiniCLEAN(Ar)
SuperCDMS
DEAP-3600
CLEAN(Ne)
XENON1T
CLEAN(Depleted Ar)
f_n/f_p= 1
σ_{SI}^p [cm^2]
f_n/f_p= −0.7
f_n/f_p= −0.82
m_χ [GeV]
10.
100.
10^3
10^4

IVDM at the LHC

DM: SM gauge singlet Dirac fermion

$$\mathcal{L}_I \supset \frac{1}{\Lambda^2}(g_U \bar{u}_R \gamma_\mu u_R \;+\; g_D \bar{d}_R \gamma_\mu d_R)(\bar{\chi}\gamma^\mu \chi)$$

Can we measure the magnitude and sign of g_D/g_U for $g_U^2 + g_D^2 = 1$?

For the magnitude, use the fact that up and down quarks couple differently to photons but identically to gluons

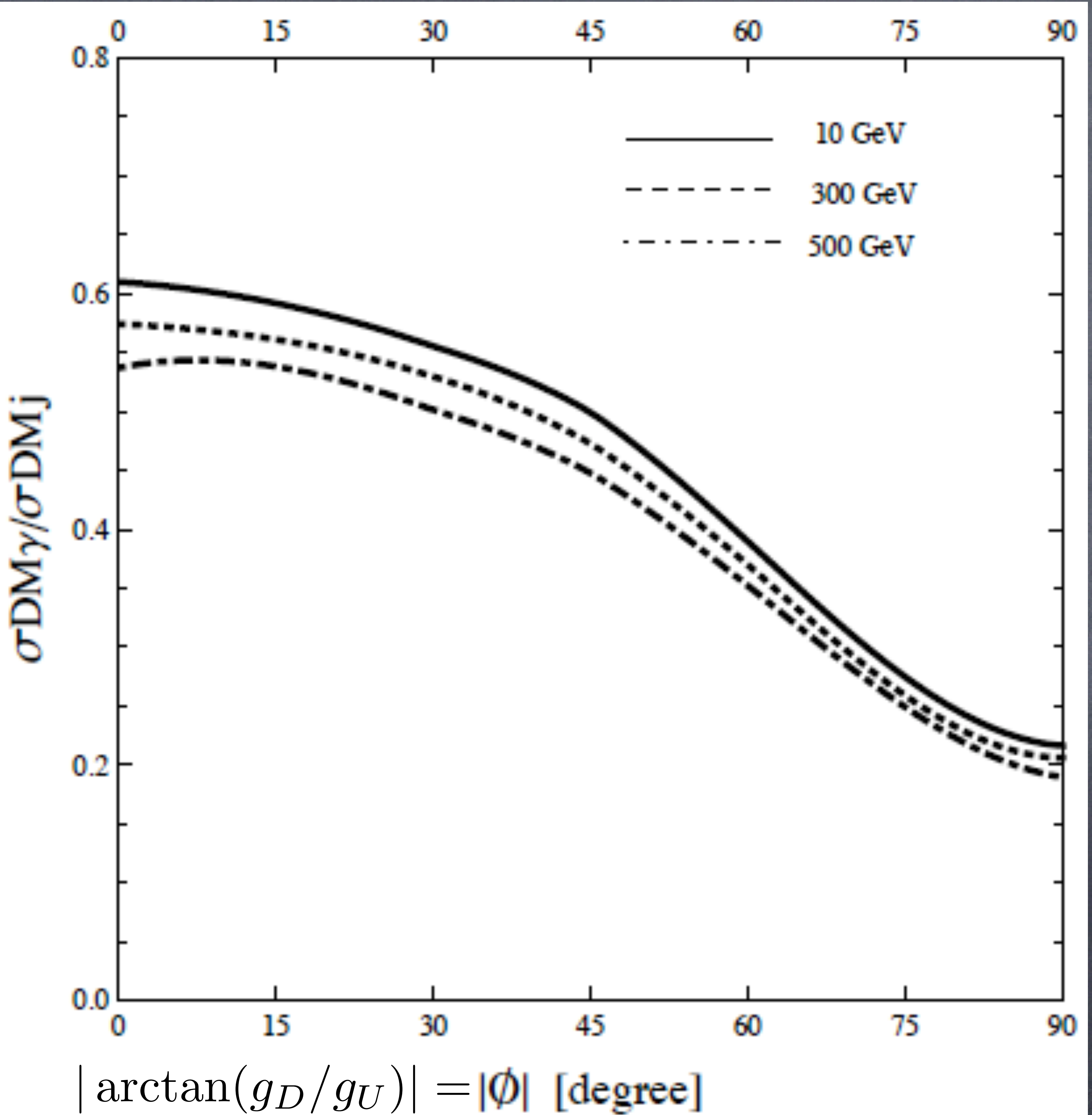
To find $|g_D/g_U|$, compare signal cross sections in the monophoton+$\not{E}_T$ and monojet+$\not{E}_T$ channels

Monojet:

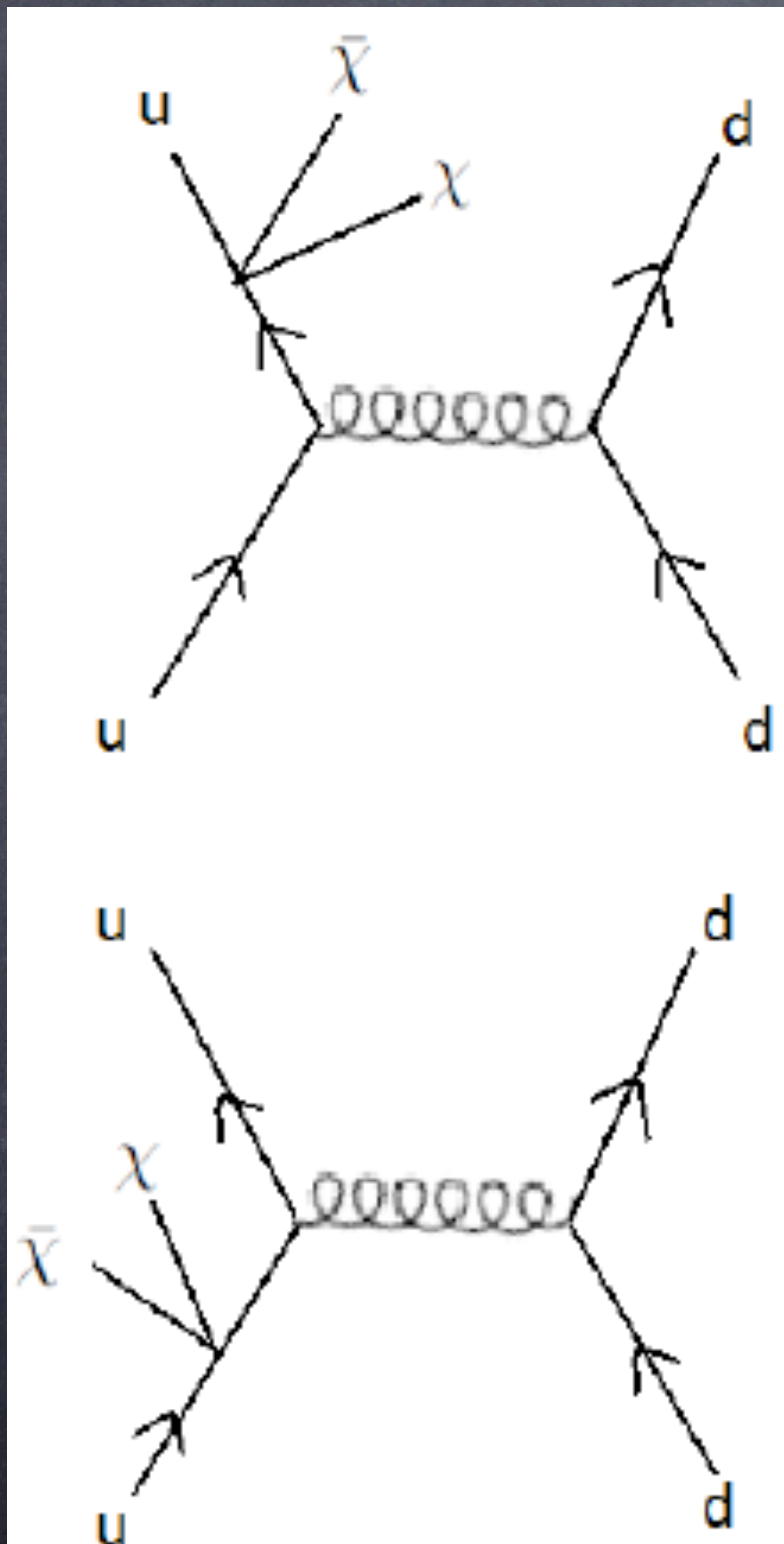
signal	background
$gq \to q\chi\bar{\chi}$	$Z(\to \nu\nu) + \text{jet}$
$q\bar{q} \to g\chi\bar{\chi}$	$W(\to \tau\nu) + \text{jet}$
	$W(\to l\nu) + \text{jet}$

Monophoton:

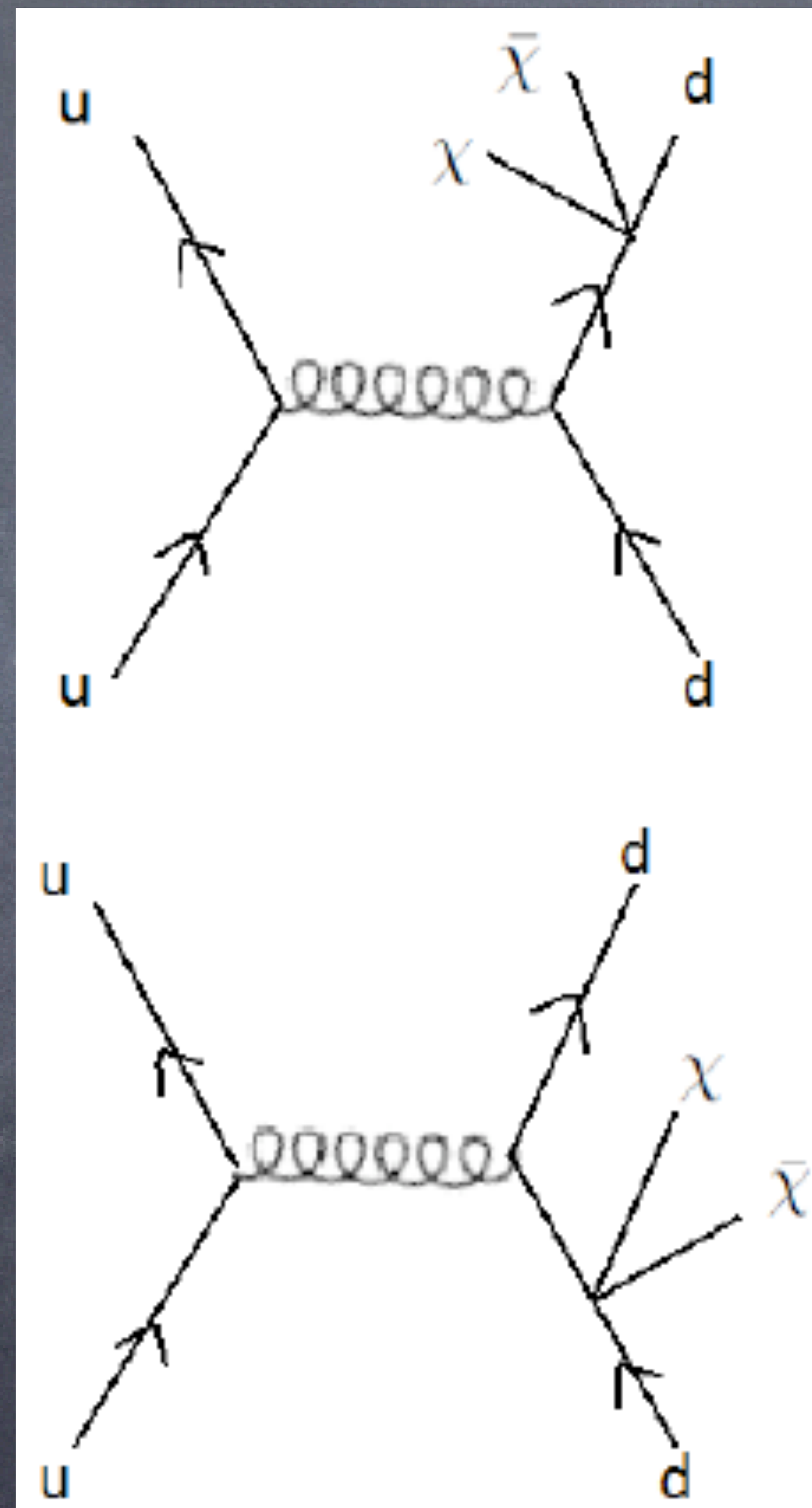
signal	background
$q\bar{q} \to \gamma\chi\bar{\chi}$	$Z(\to \nu\nu) + \gamma$
	$Z(\to \nu\nu) + \text{jet} \quad (\text{jet misIDed})$
	$W(\to e\nu) \quad (\text{e misIDed})$


10 GeV
300 GeV
500 GeV
σDMγ/σDMj
0.0
0.2
0.4
0.6
0.8
0
15
30
45
60
75
90
| arctan(g_D/g_U)| = |ϕ| [degree]

Dijet+ $\not\!\!E_T$ is sensitive to the interference between the diagrams on the left and right



$\propto g_U$



$\propto g_D$

background

$$qg \rightarrow qgZ(\nu\nu)$$

$$gq \rightarrow qg\chi\bar{\chi}$$

$$qq' \rightarrow qq'Z(\nu\nu)$$

$$qq \rightarrow qq\chi\bar{\chi}$$

To find $sgn(g_D/g_U)$, compare signal cross sections in the dijet+$\not{E}_T$ and monojet+$\not{E}_T$ channels