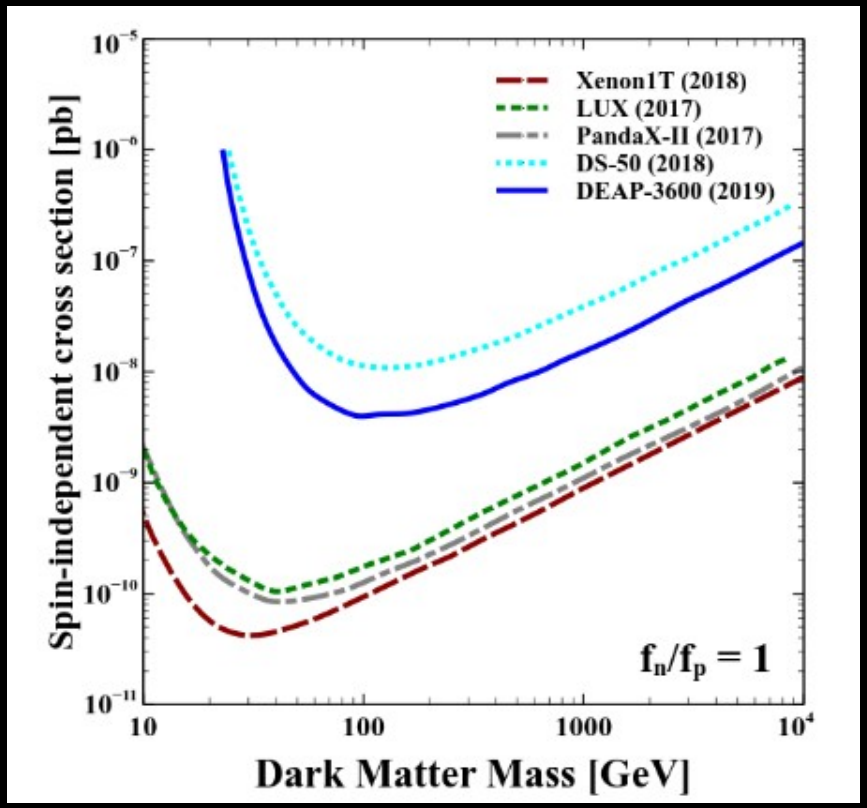
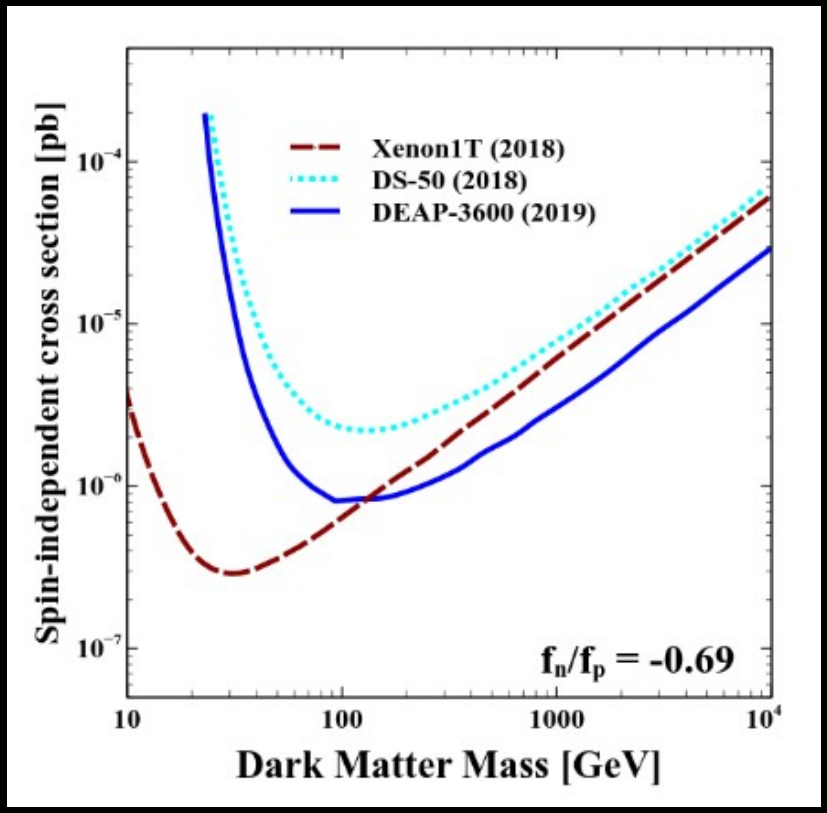
Isospin-violating dark matter





Based on JCAP 1904, 041 and PRD95 (2017) no.5, 055015

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Escuela de Física
UPTC, 2019

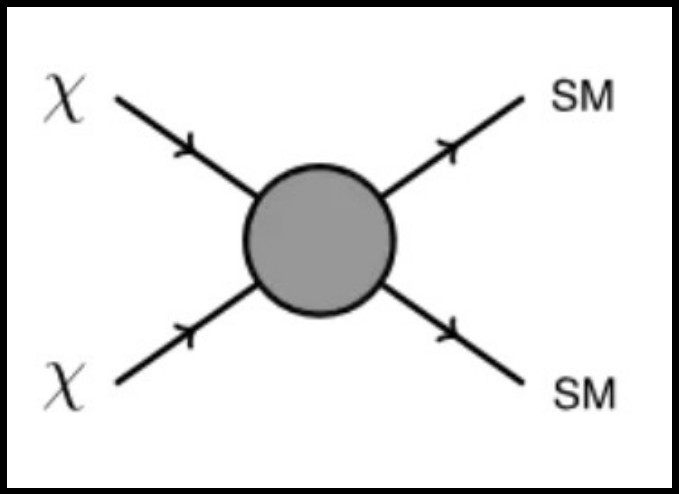
We want to determine the fundamental nature of the dark matter particle

Is it a WIMP, an axion or something else?

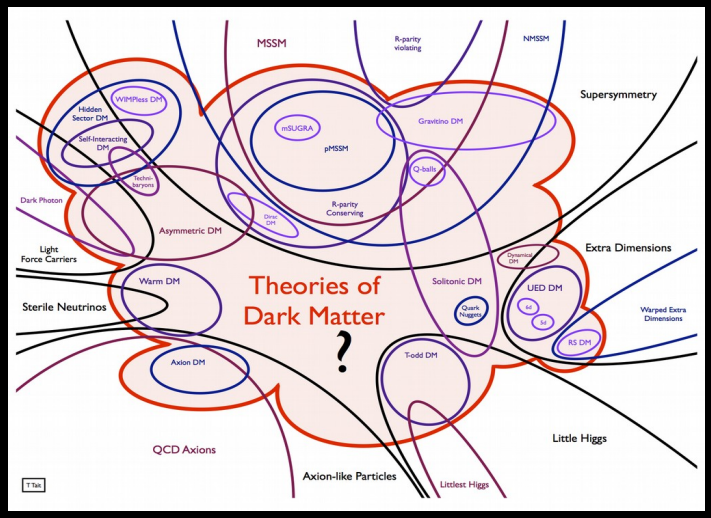
What are its mass, spin, and quantum numbers?

What is the correct new physics model for DM?

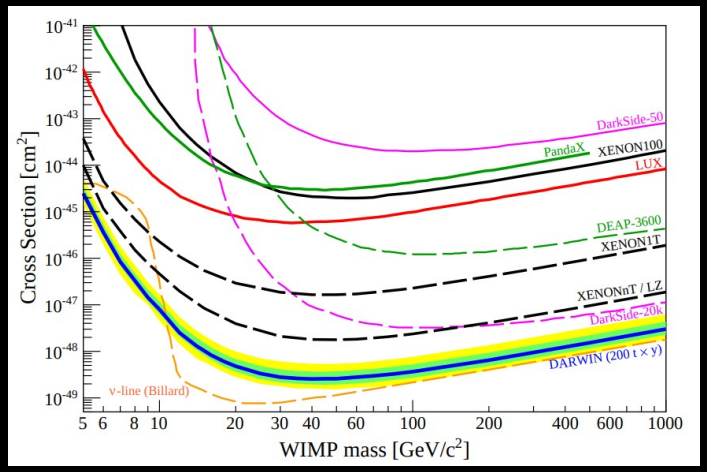
WIMPs are very special dark matter candidates



Their production

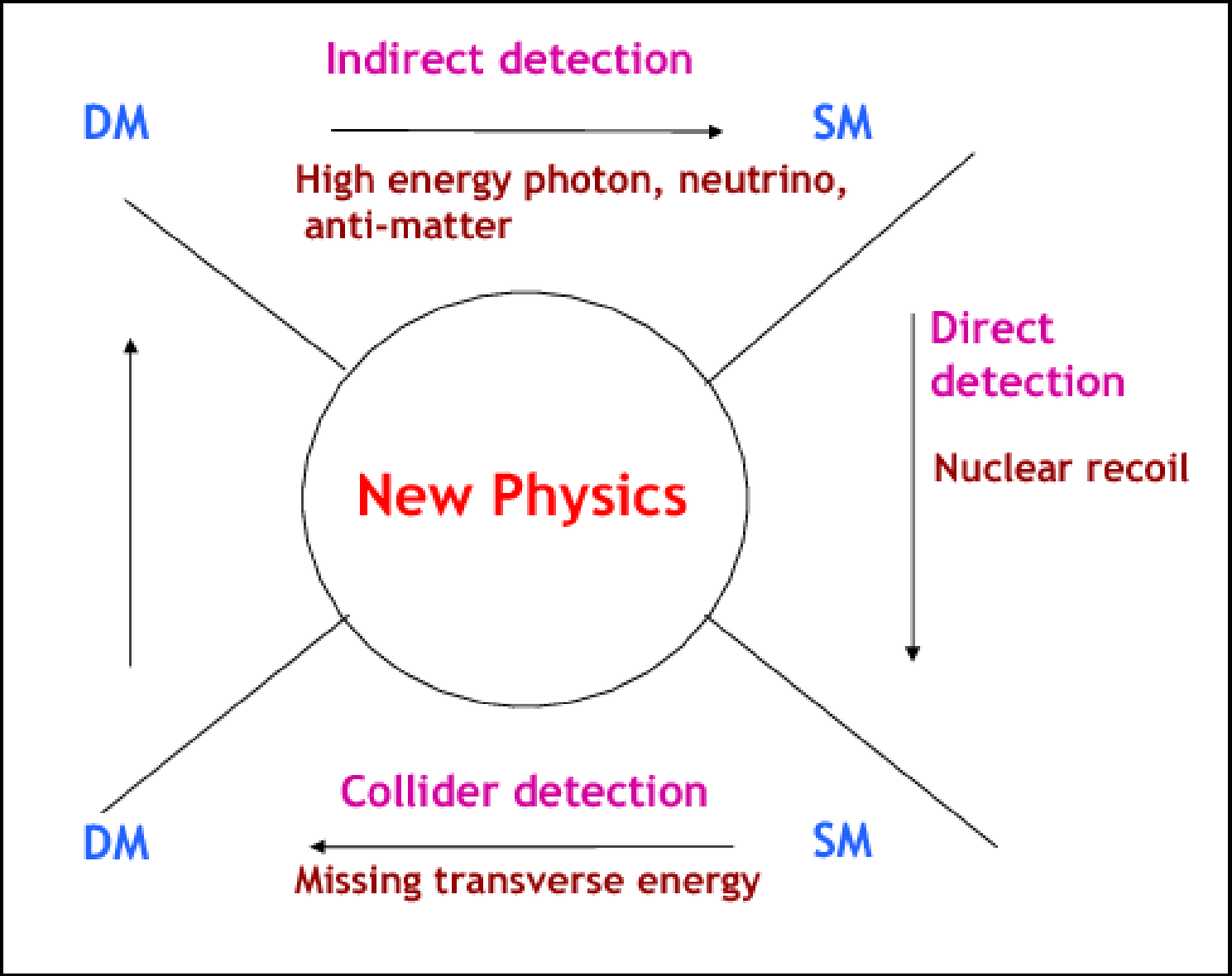


Their prevalence



Their detectability

WIMPs can be tested in different ways

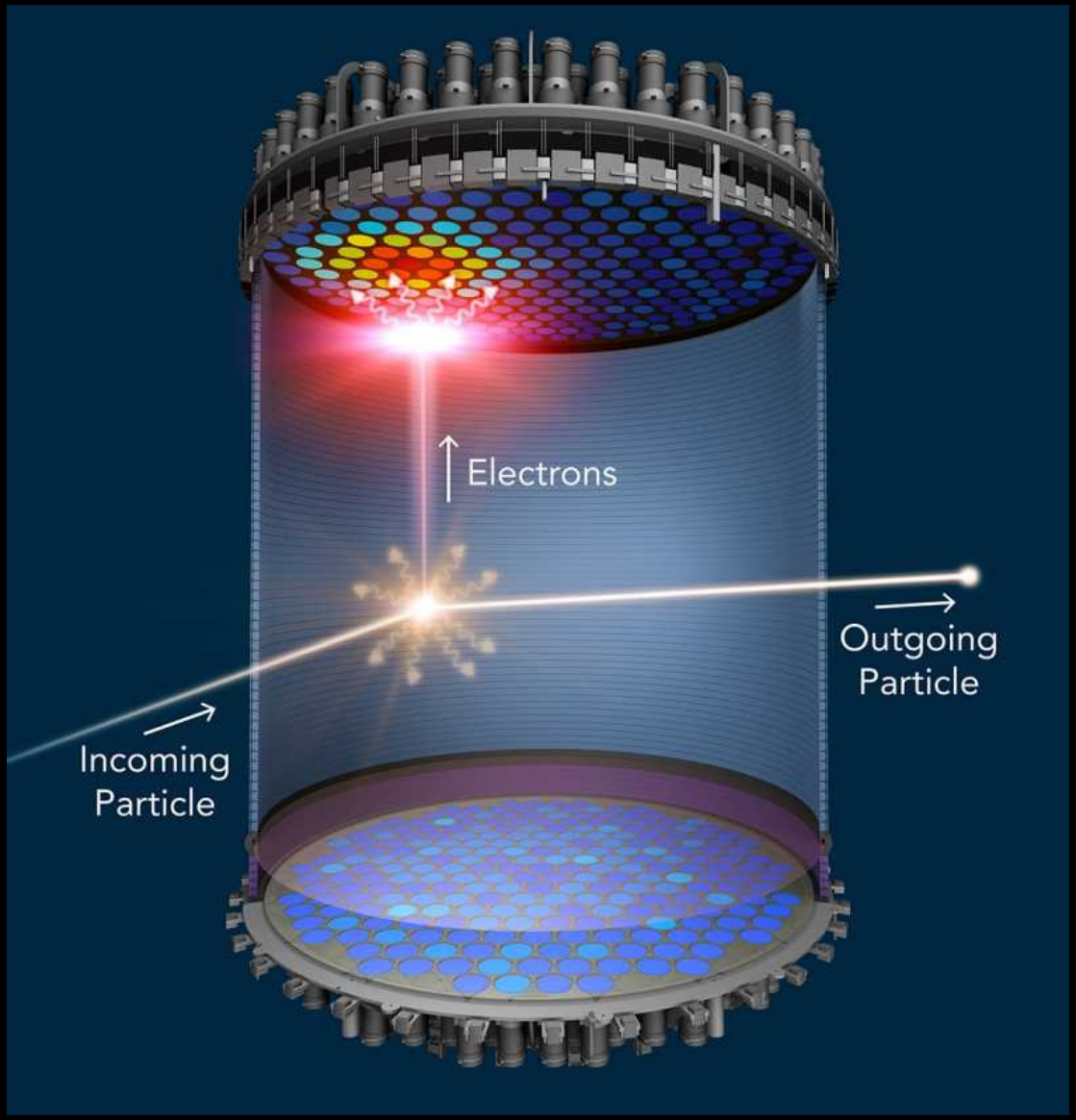


Direct detection experiments search for nuclear recoils induced by dark matter

It is a mature technology

Strong limits over the past years

And they will get more stringent



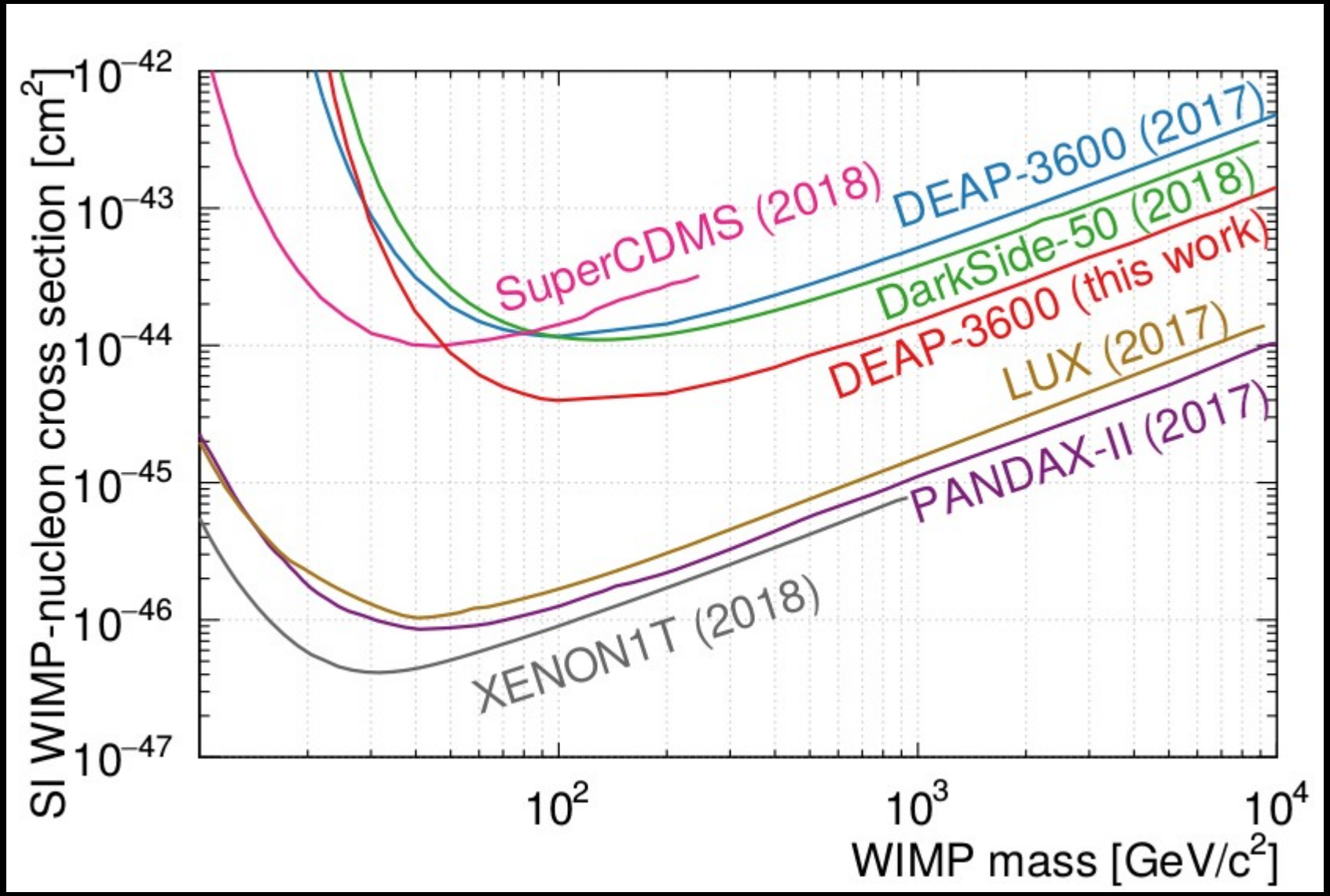
The experimental signal depends on just 3 particle physics parameters: f^p, f^n, m_χ

$$\frac{dR}{dE}(E,t) = \frac{\rho_0}{m_\chi \cdot m_A} \cdot \int v \cdot f(\mathbf{v},t) \cdot \frac{d\sigma}{dE}(E,v)\, \mathrm{d}^3 v$$

$$\frac{d\sigma}{dE} = \frac{m_A}{2\mu_A^2 v^2} \cdot (\sigma_0^{\mathrm{SI}} \cdot F_{\mathrm{SI}}^2(E) + \sigma_0^{\mathrm{SD}} \cdot F_{\mathrm{SD}}^2(E)).$$

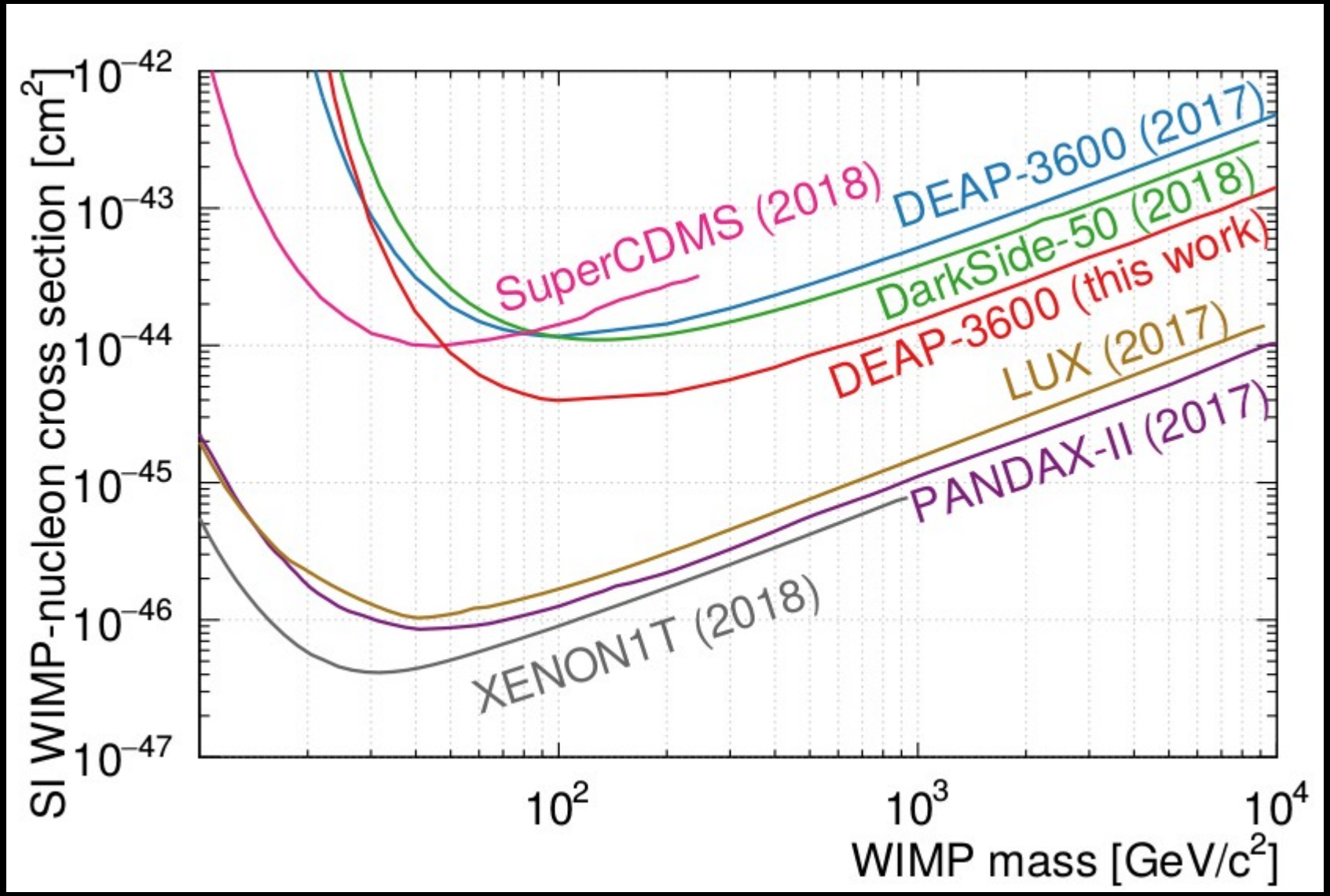
$$\sigma_0^{\mathrm{SI}} = \sigma_p \cdot \frac{\mu_A^2}{\mu_p^2} \cdot [Z \cdot f^p + (A-Z) \cdot f^n]^2$$

Direct detection limits have been improving over the past years



1902.04048

How come these limits are reported in a plane when they depend on 3 parameters?



These limits all assume that $f^p = f^n$: isospin-conservation

$$\sigma_0^{\mathrm{SI}} = \sigma_p \cdot \frac{\mu_A^2}{\mu_p^2} \cdot [Z \cdot f^p + (A - Z) \cdot f^n]^2$$

There is no support whatsoever for this assumption. The default dark matter scenario should be $f^p \neq f^n$ (isospin-violating DM)

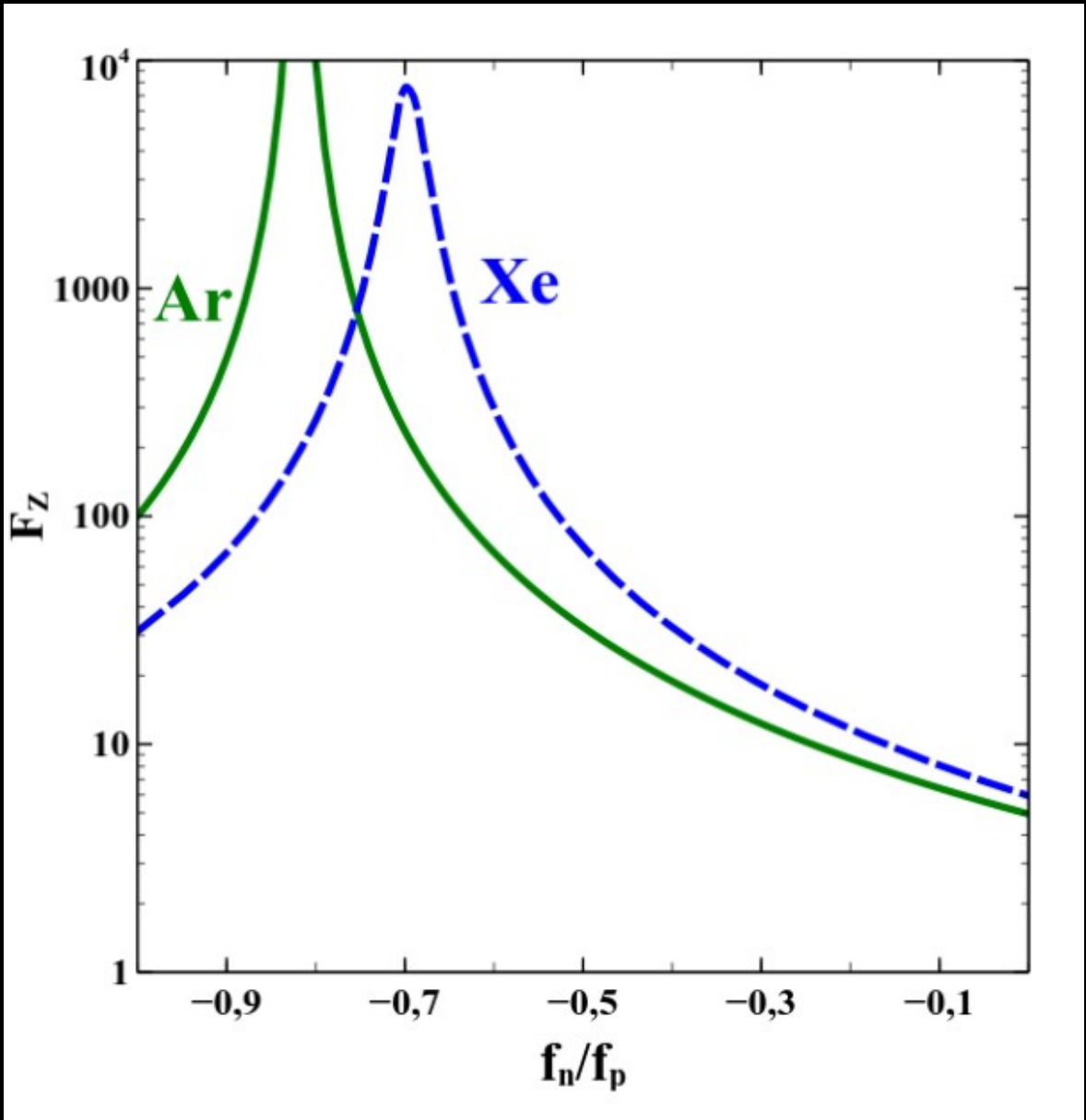
Several simple dark matter models give rise to isospin-violating DM

Dark-Photon Mediation: $f_n/f_p = 0$

Z Mediation: $f_n/f_p = -12.5$

Light Squark-Mediation: $f_n/f_p = 0.7$ ($\tilde{u}$) or 1.5 ($\tilde{d}$)

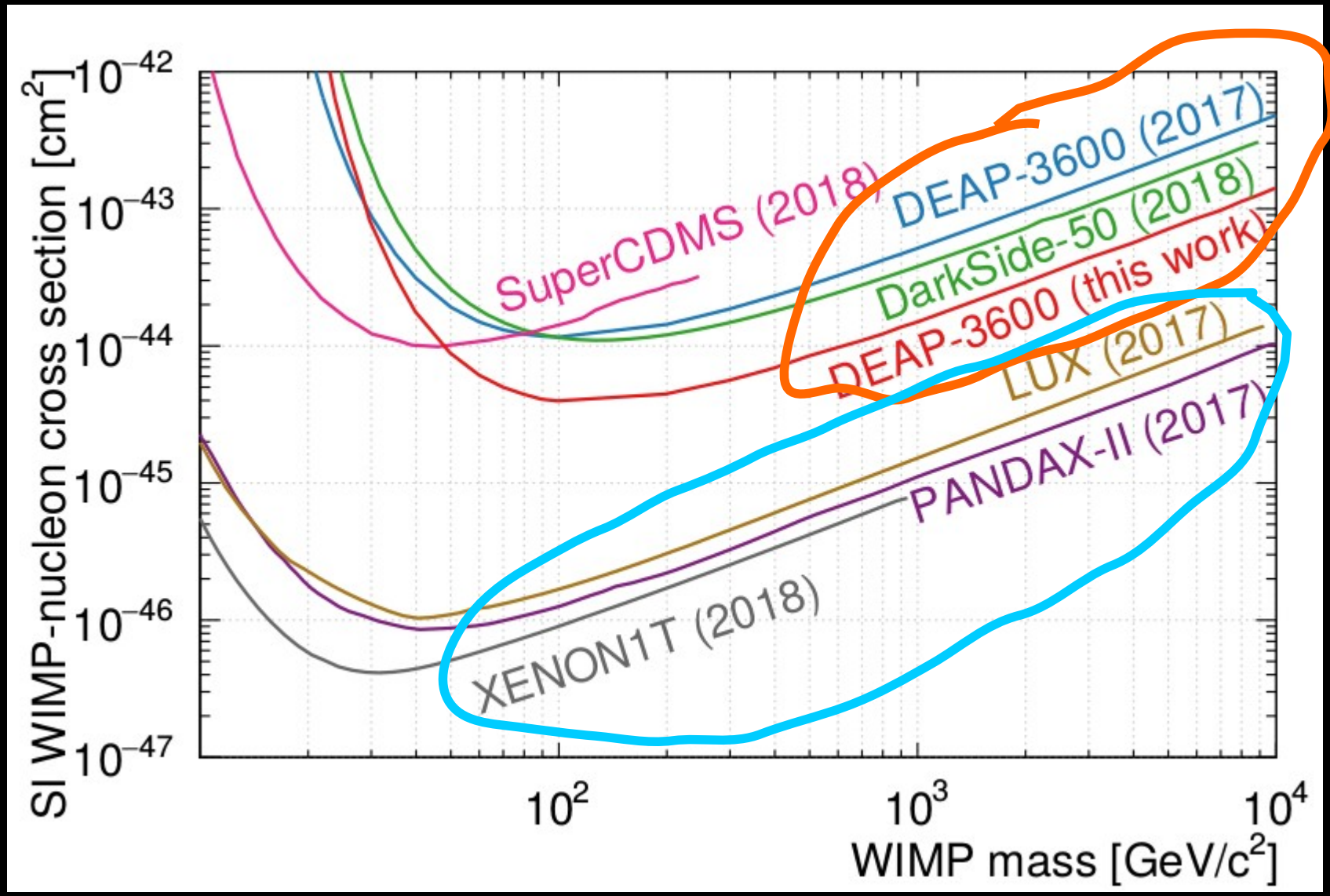
For isospin-violating DM, cancellations may occur for certain values of f^p/f^n



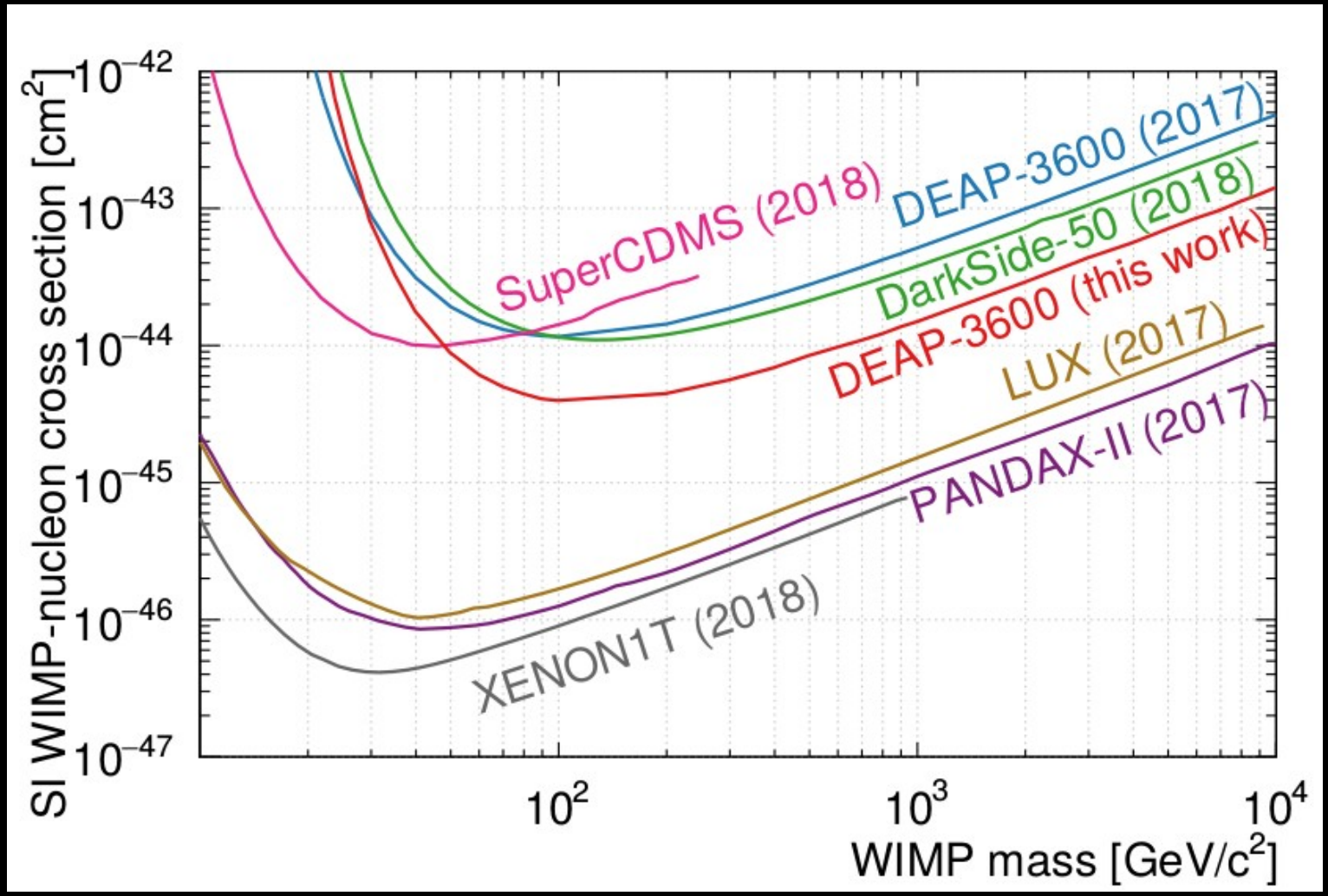
F_z is the suppression in the sensitivity

And they strongly depend on the target nucleus

We currently have limits from Xenon and Argon experiments

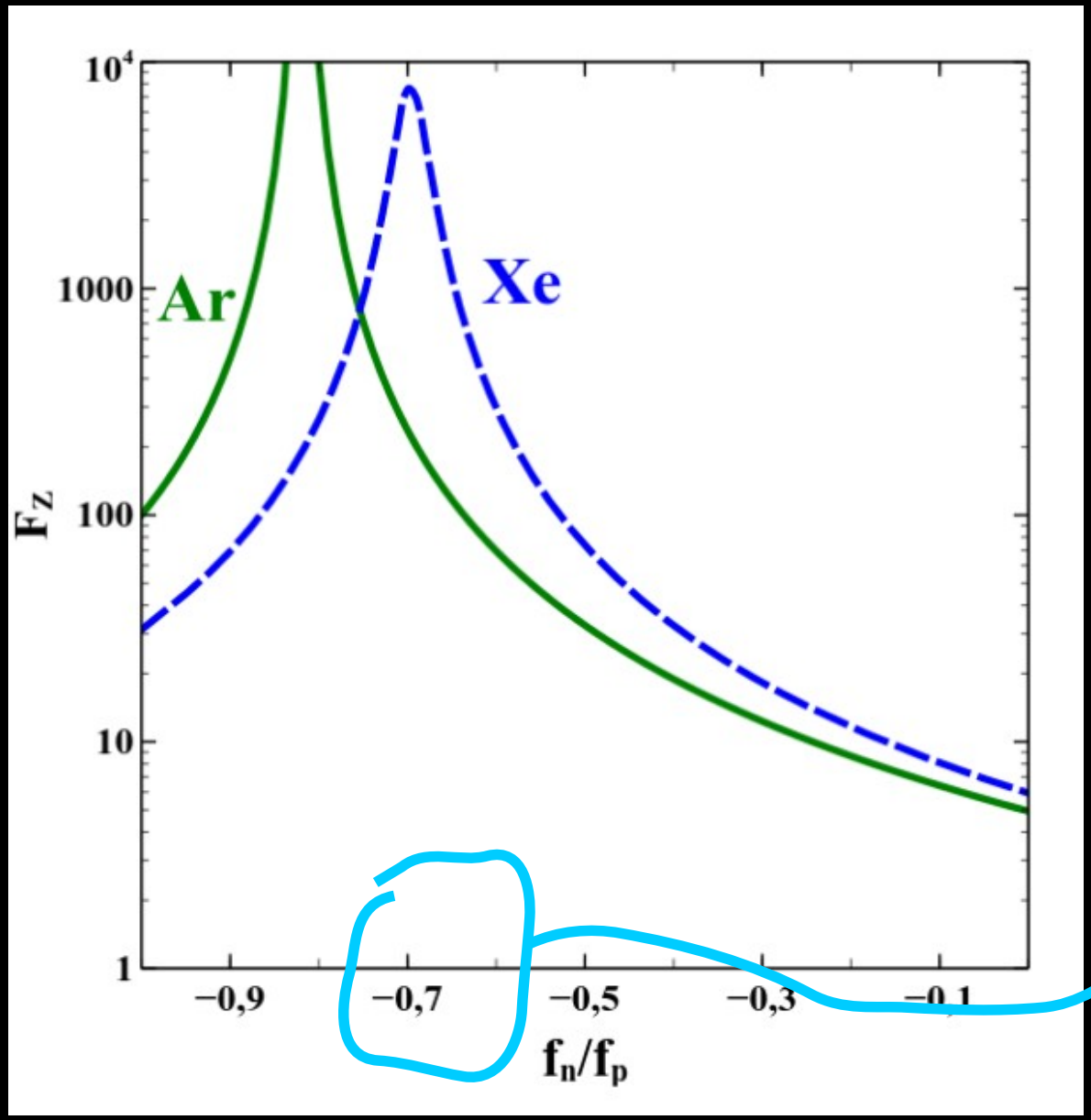


The recent DEAP-3600 limits look irrelevant but they are not



The region above the lines is excluded

For isospin-violating DM, the experimental limits need to be reevaluated

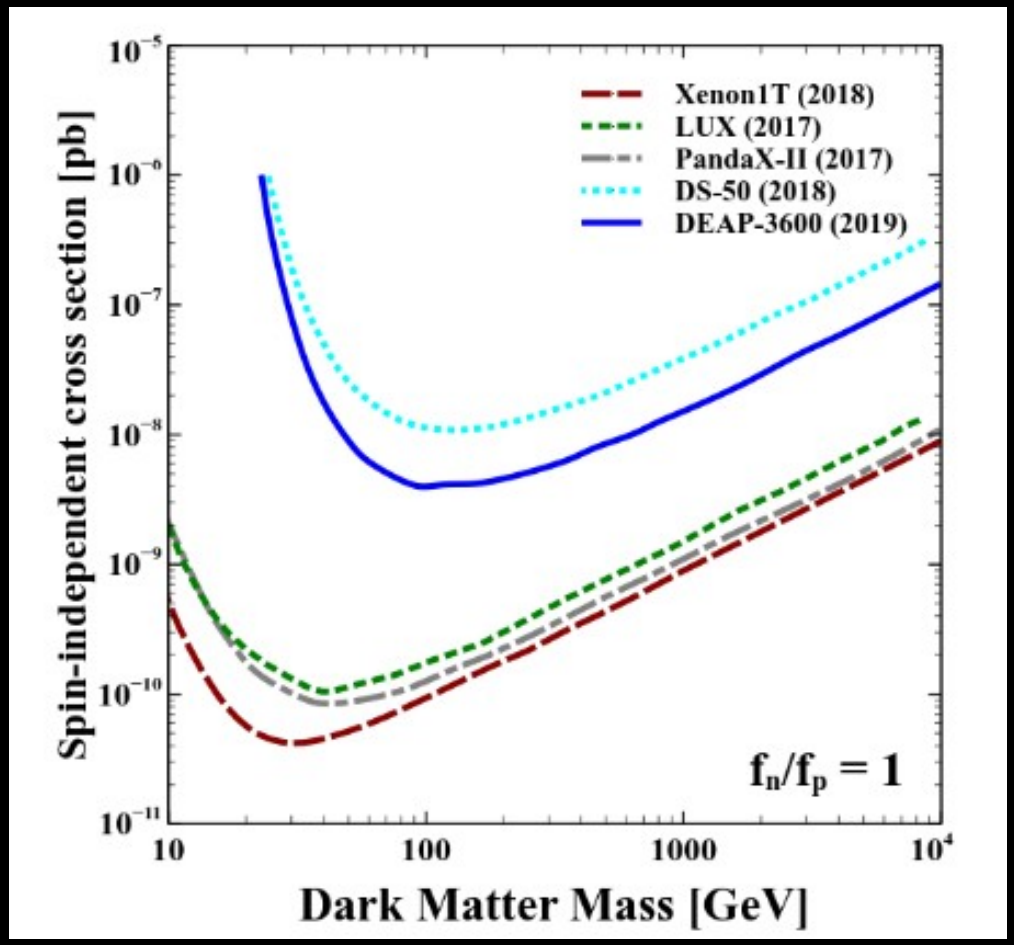


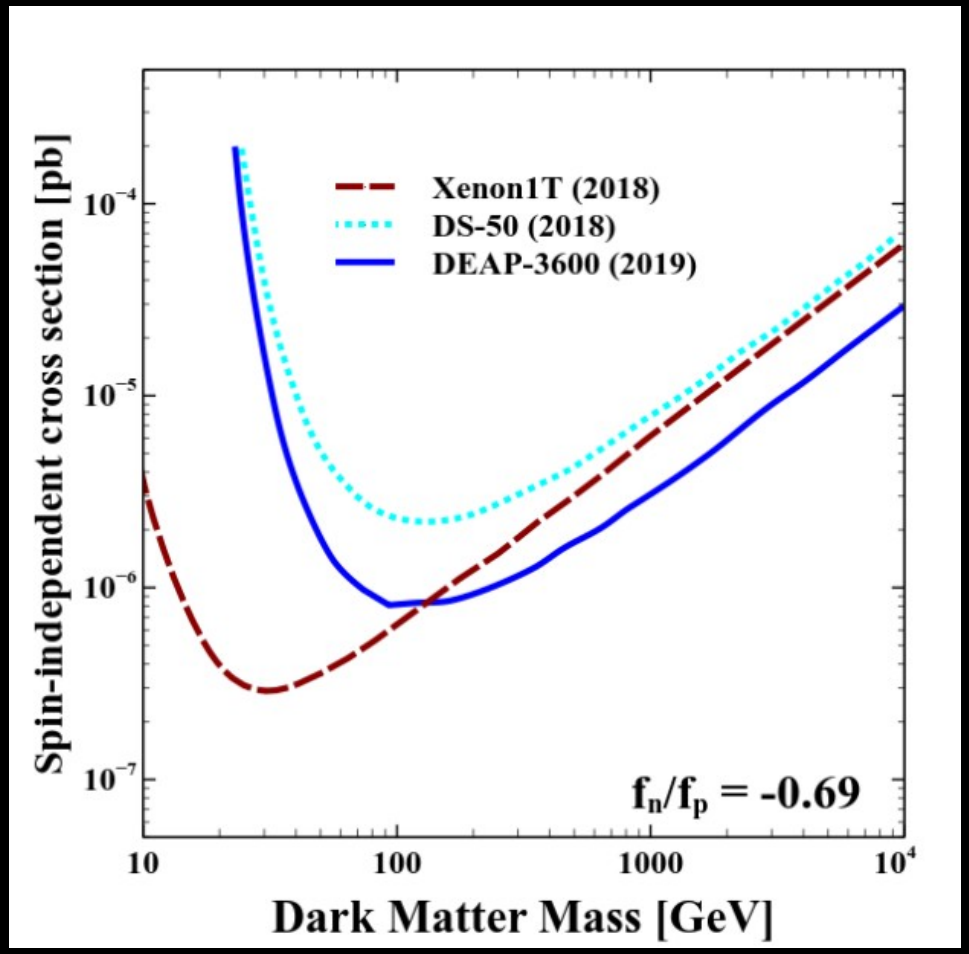
The limits will depend on f^n/f^p

For $f^n/f^p \approx -0.7$ the changes are important

Xenonphobic dark matter

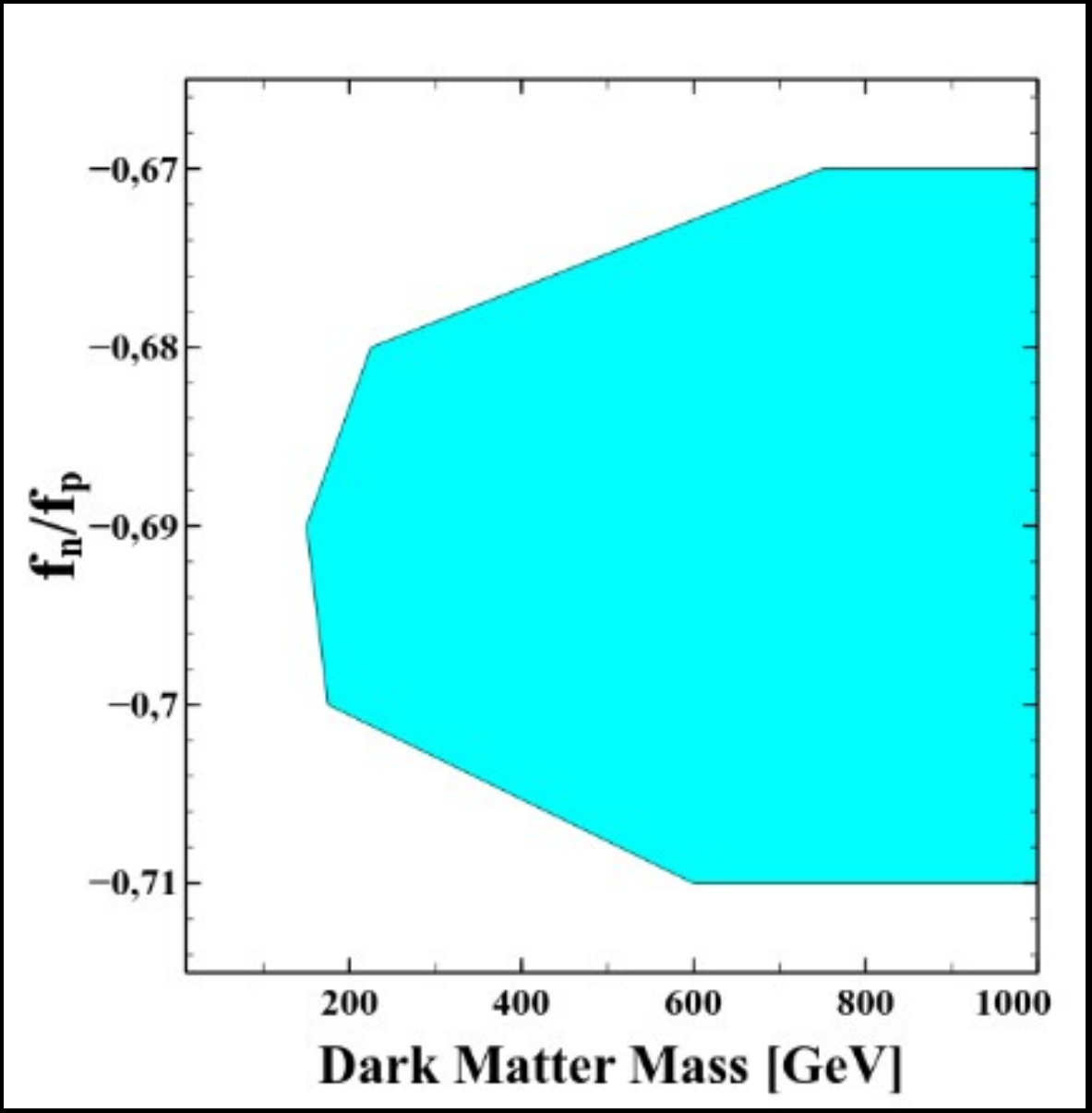
The DEAP-3600 limit can actually be more constraining



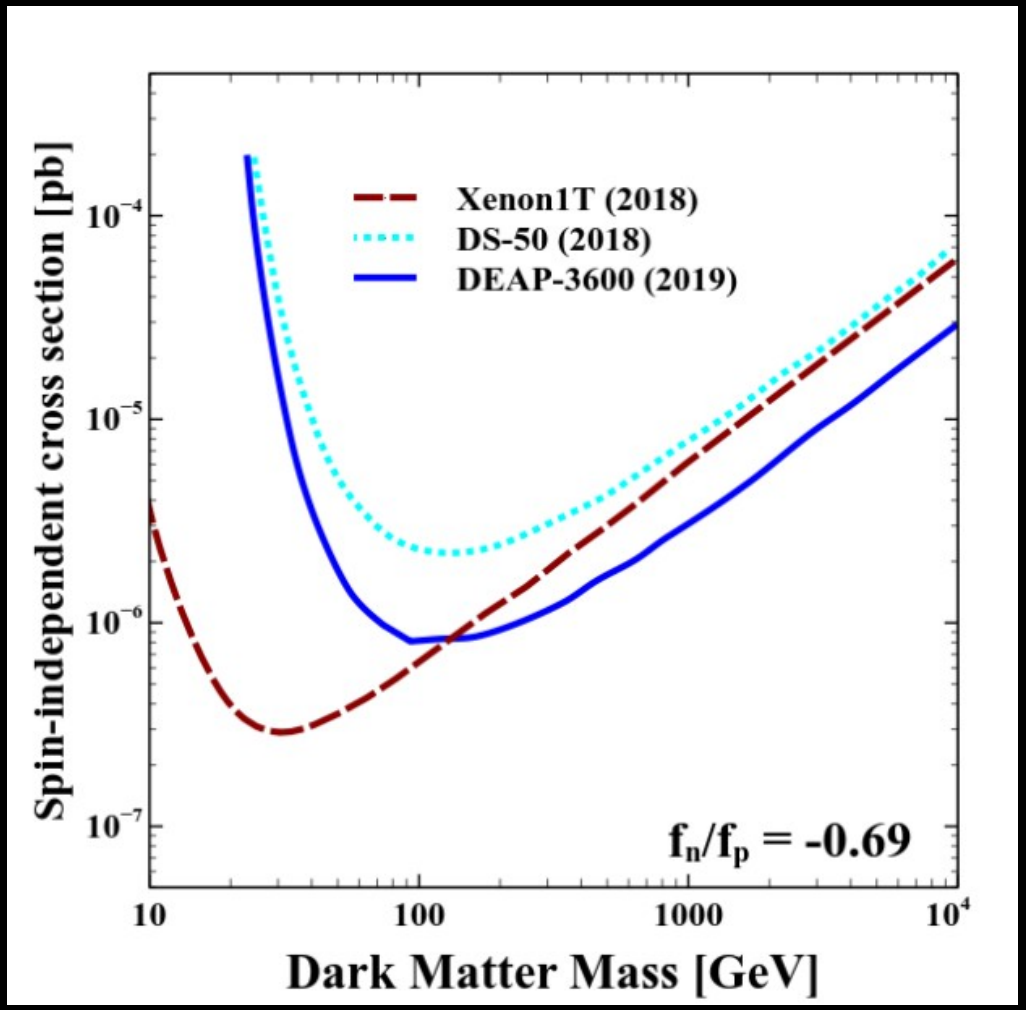


The DEAP-3600 experiment is probing new regions of parameter space!

There is a region of parameter space where DEAP-3600 is most constraining



This is a new example of complementarity among different direct detection targets

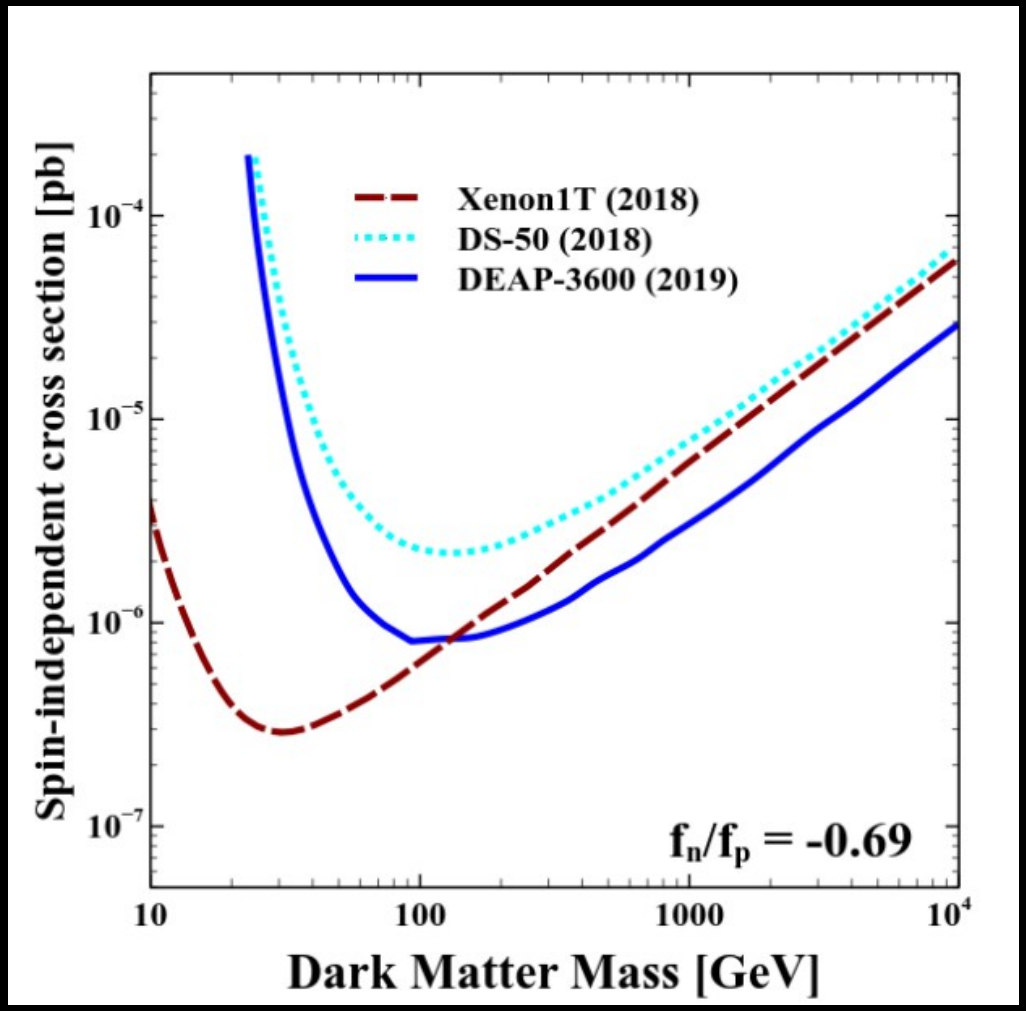


The end of the Xenon dominated epoch

The beginning of a new era:

- **Testing isospin conservation**
- **Majorana or Dirac DM**

Isospin-violating DM is a well motivated scenario that has become testable



No reason, a priori, to expect $f^n/f^p = 1$

Current limits should reflect this fact

Future signals may be used to determine f^n/f^p