

dark matter wimp search in noble liquids

DARWIN

Scientific Reach of DARWIN

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Presented by Thomas Jacques

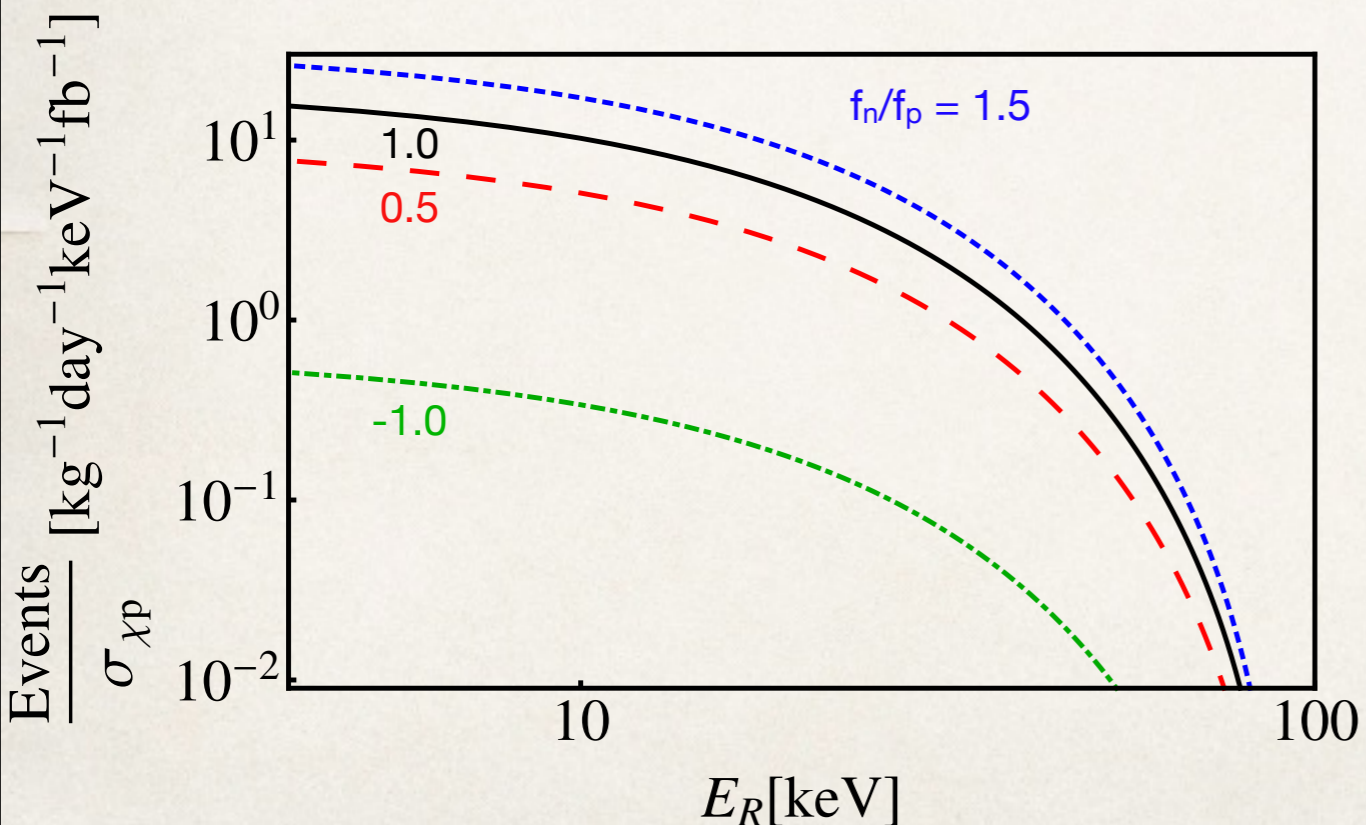
Detecting a WIMP

$$\frac{dR}{dE_R} = \frac{\sigma_{\chi p}}{2m_\chi \mu_{\chi N}} \left(Z + \frac{f_n}{f_p} (A - Z) \right)^2 F^2(E_R) \int_{v_{\min}}^{\infty} \rho_0 \frac{f(\vec{v})}{|\vec{v}|} d^3v$$

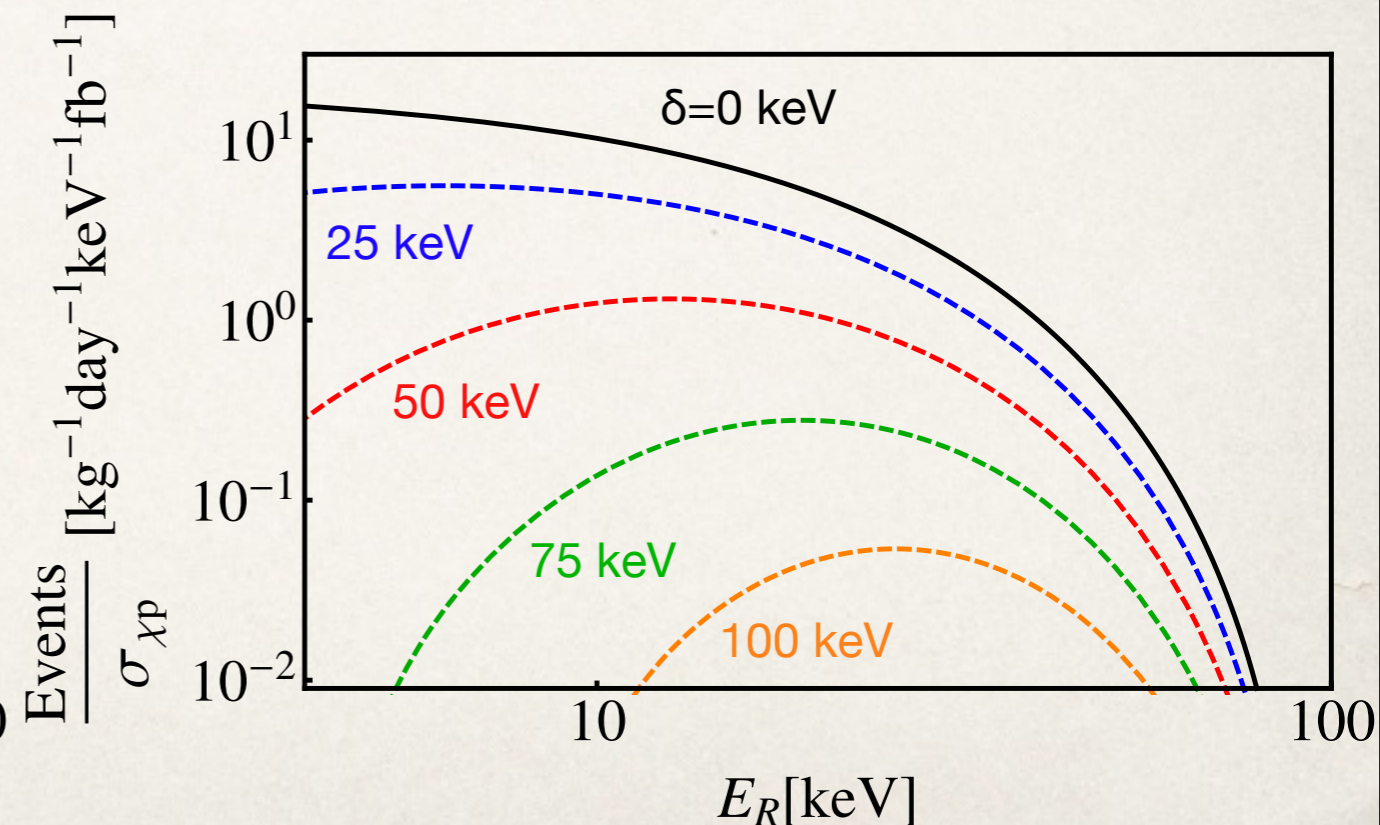
(Spin Ind.)

$$v_{\min} = \frac{1}{\sqrt{2} E_R m_N} \left(\frac{E_R m_N}{\mu_{\chi N}} + \delta \right)$$

Isospin violation



Inelastic scattering

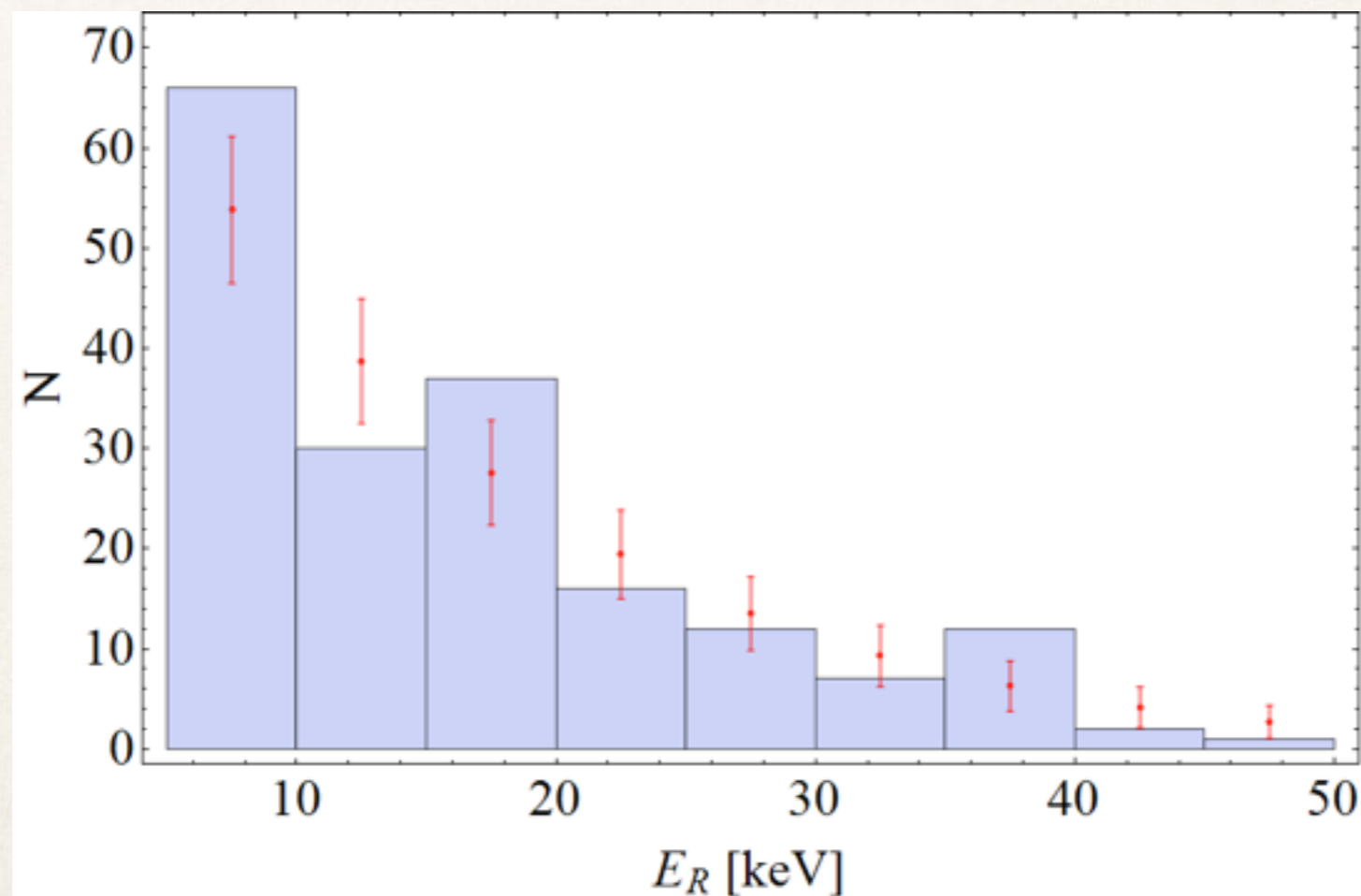


Simulation Tools

- Tool to generate limits and probability contours with a focus on generality
- Can easily be adapted to use any set of parameters, and is optimised to work with multiple detectors
- Currently includes the effects of:
 - Astrophysical uncertainties,
 - Inelastic DM,
 - Isospin violation,
 - Form factors,
 - Velocity Distributions

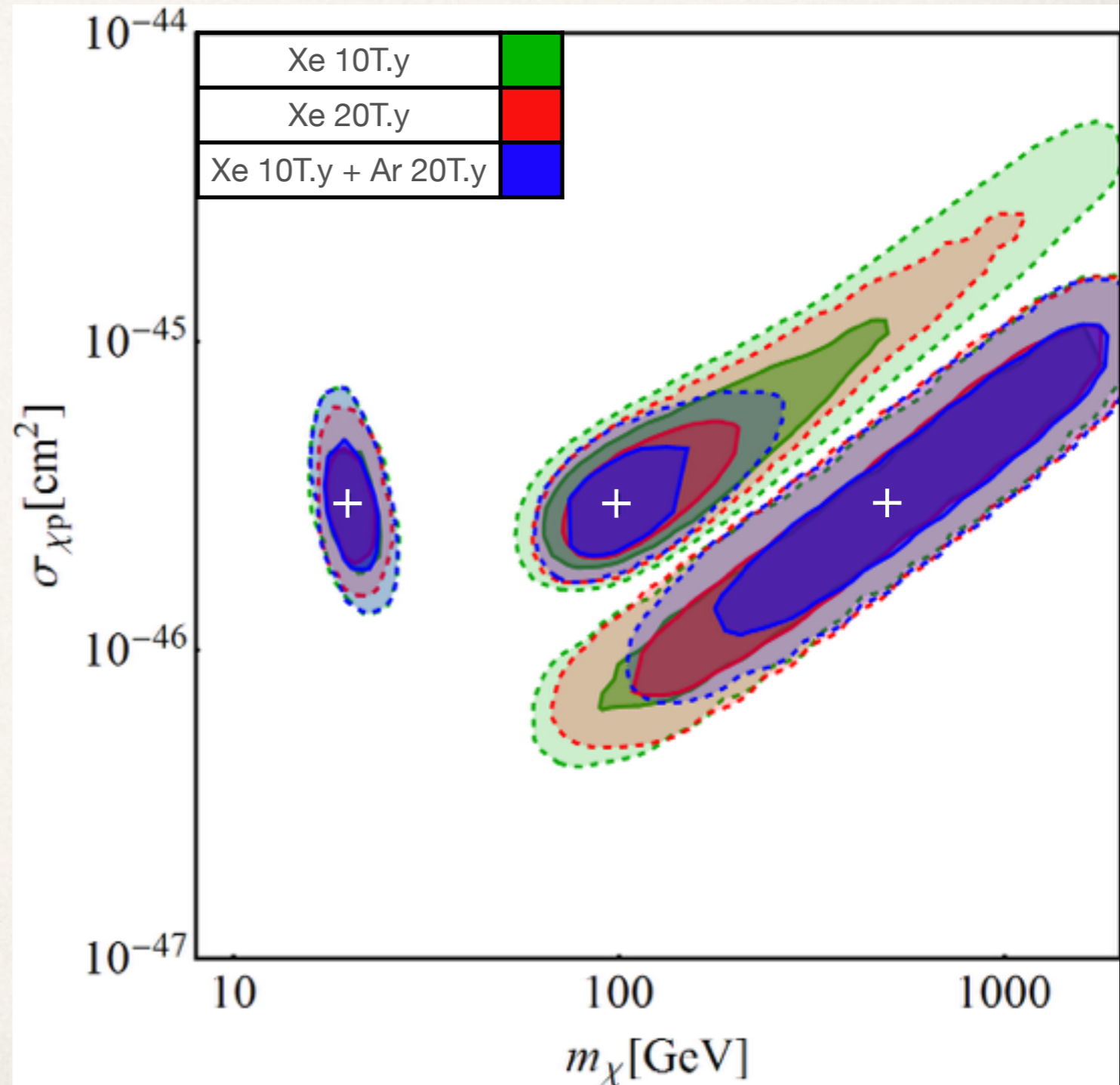
Monte-Carlo Simulations

- Generate random events
- Bayesian reconstruction
- Marginalise over uncertainties



Reconstruction

- Simulate WIMP with $\sigma_{SI}=3\times 10^{-46}$ cm^2 and $m_\chi=\{20, 100, 500\}$ GeV
- Reconstruct assuming MB phase-space, no isospin violation nor inelastic scattering
- 10 T.y Xe \sim 20 T.y Ar in sensitivity
- Moderate complementarity: Two targets together $>$ doubling either target
- Best improvement for $m_\chi \lesssim 200$ GeV

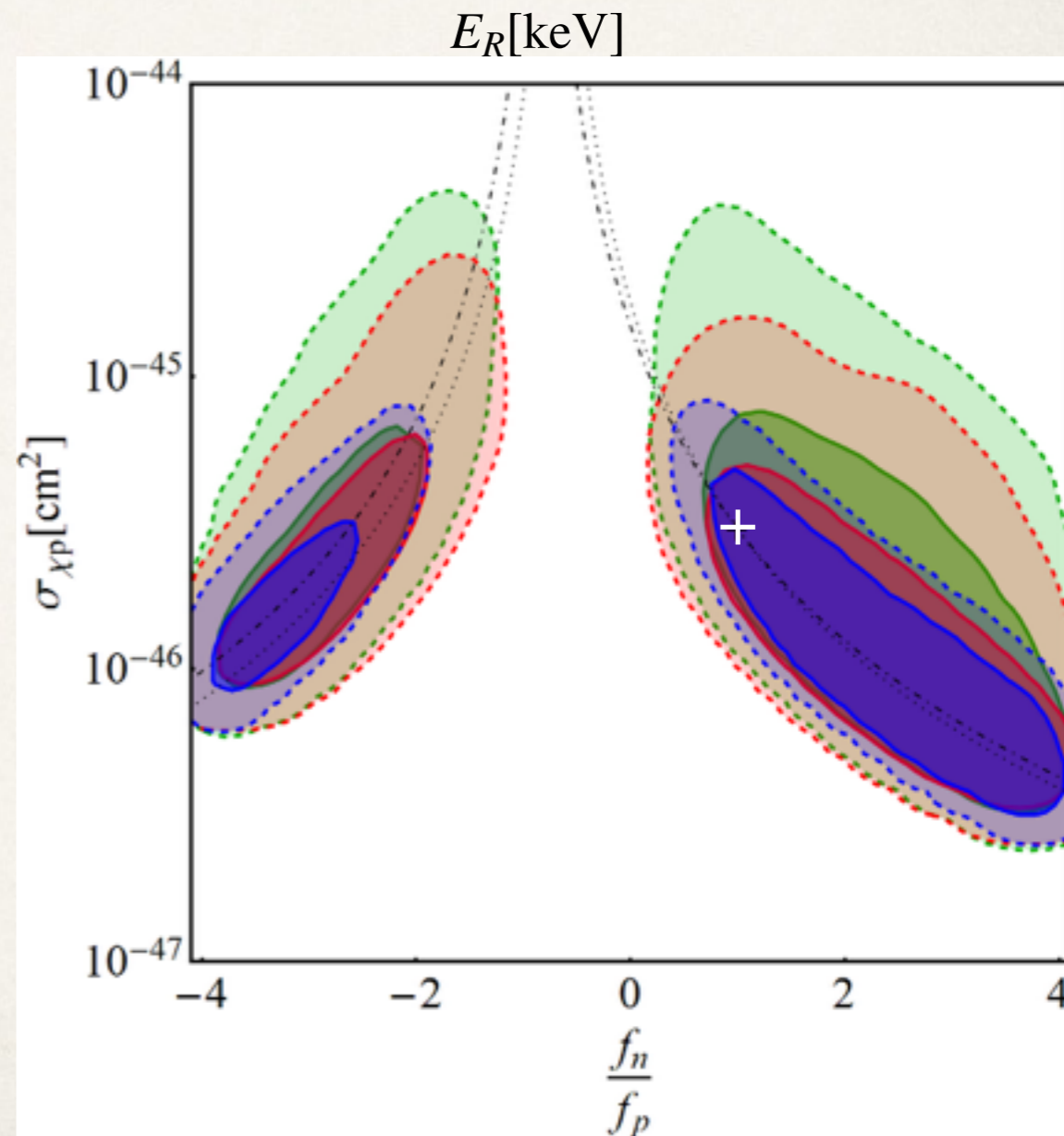
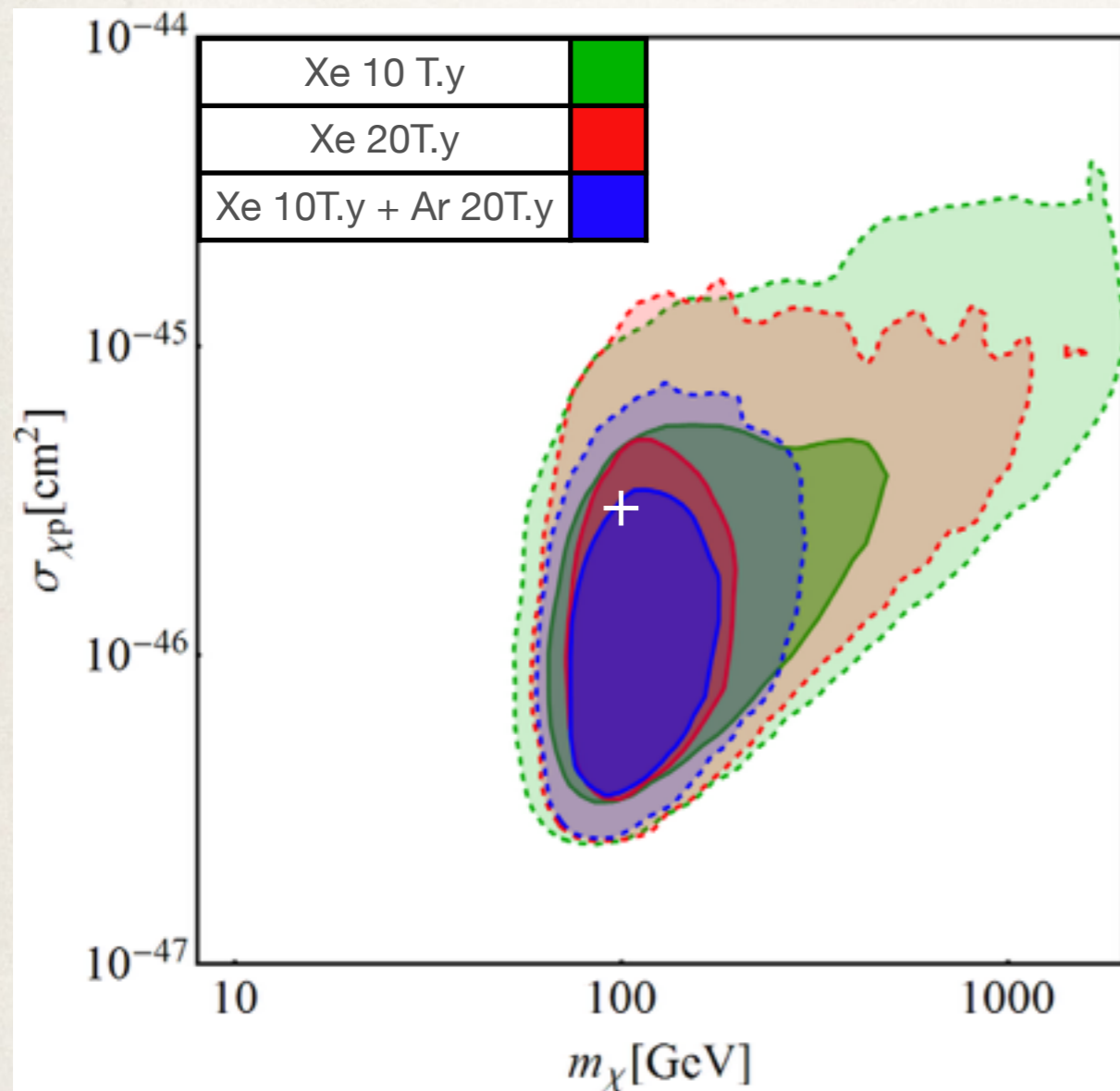
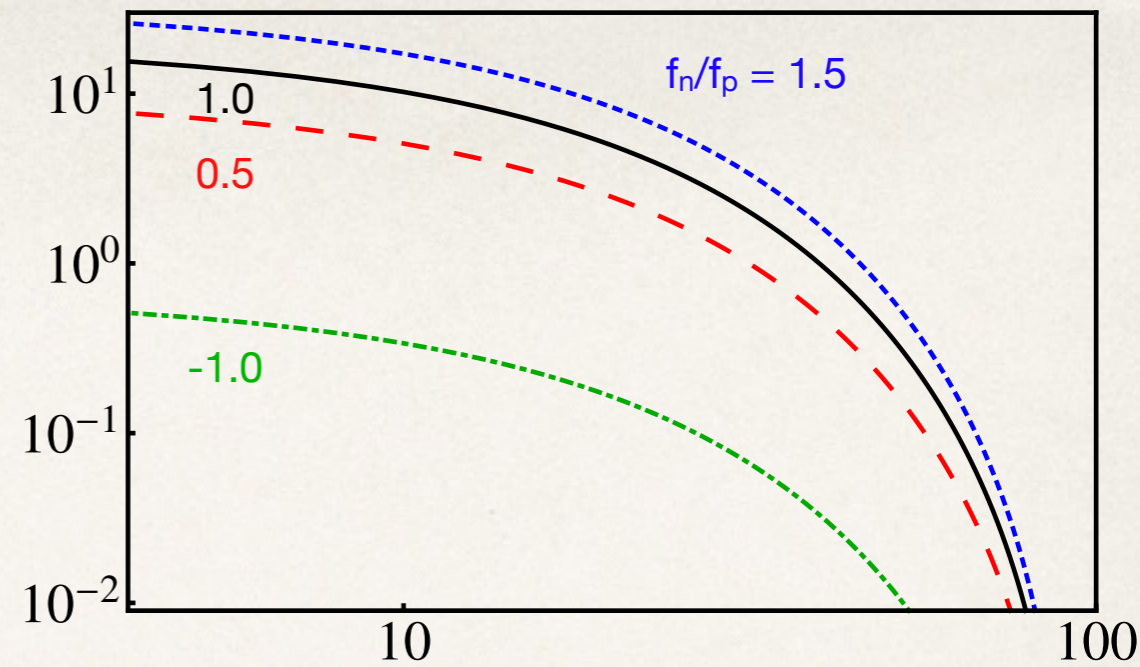


Reconstruction: Isospin Violation

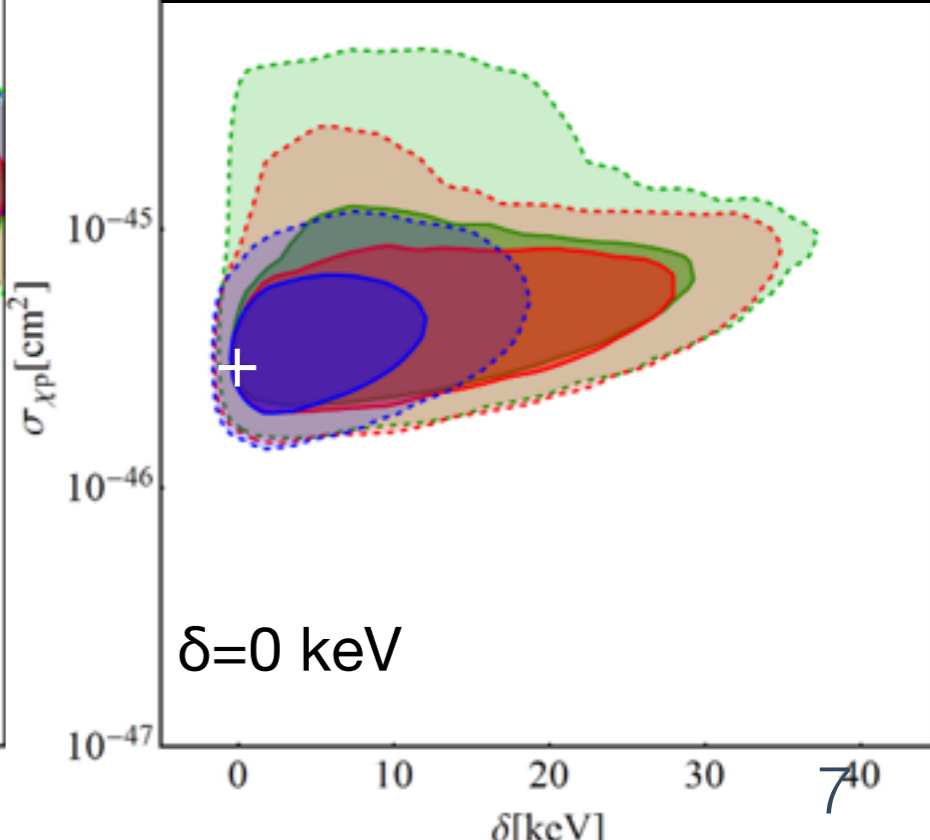
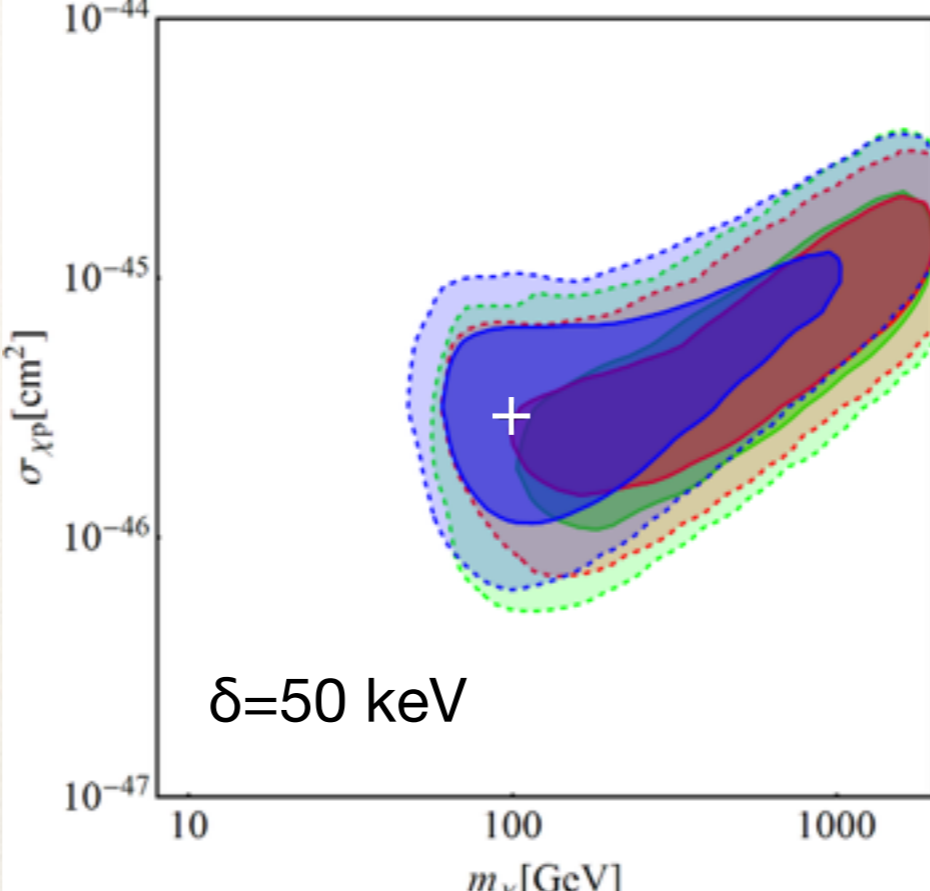
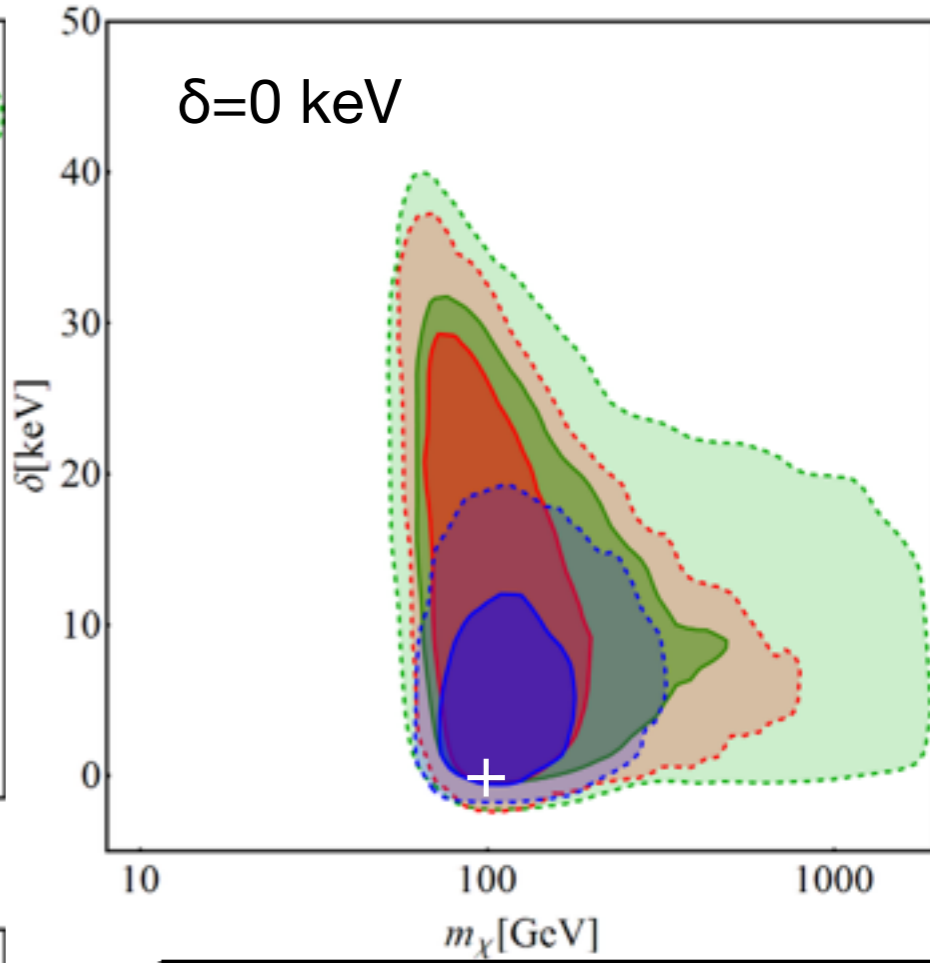
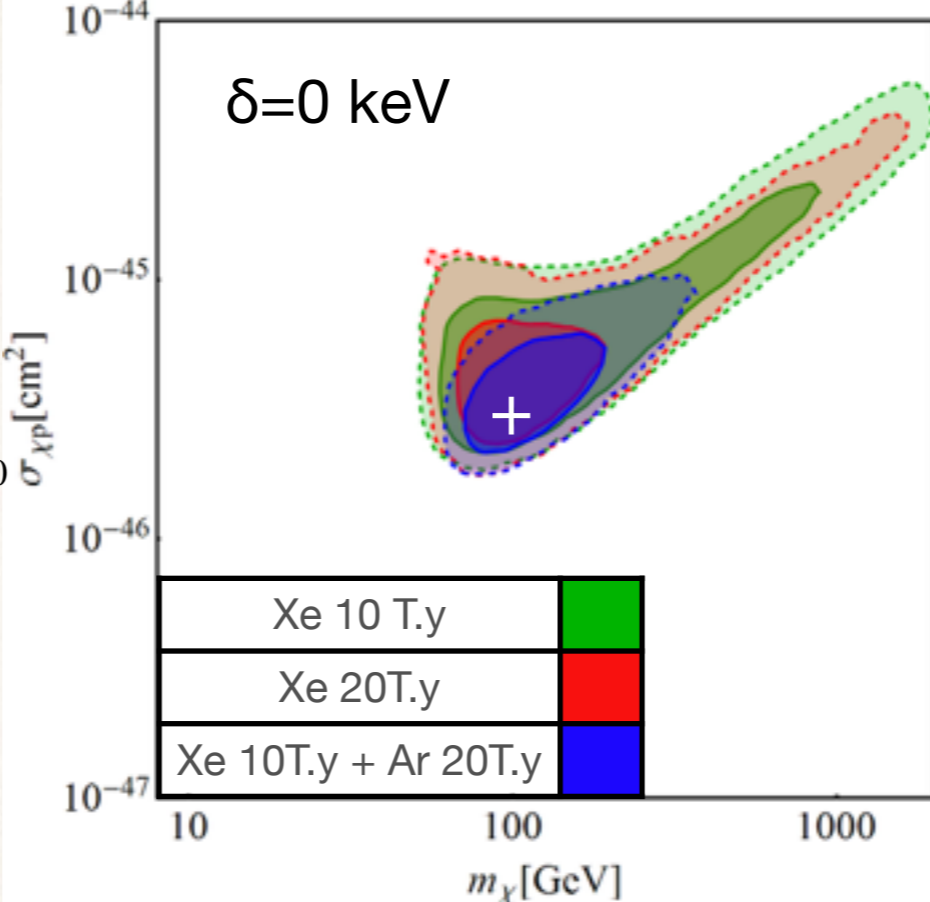
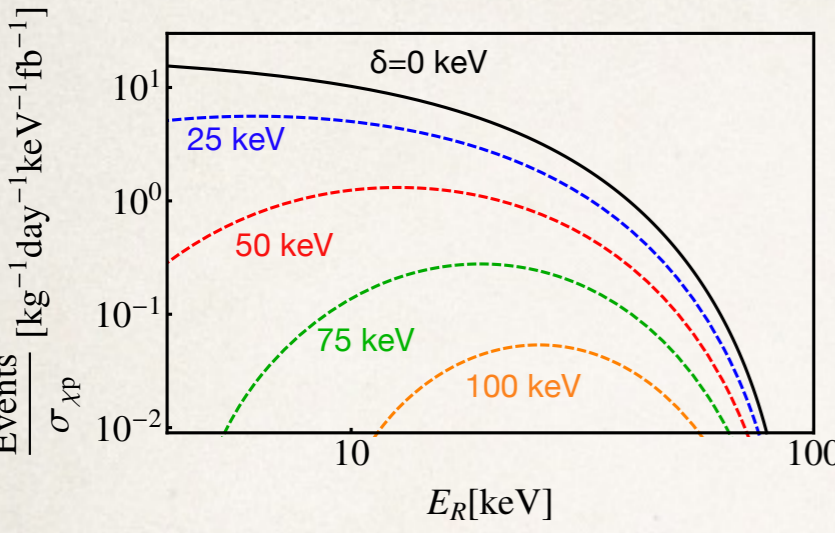
$\sigma_{SI} = 3 \times 10^{-46} \text{ cm}^2$
 $m_\chi = 100 \text{ GeV}$

$f_n/f_p = 1$ during simulation,
 allowed to vary during
 reconstruction

$\frac{\text{Events}}{\sigma_{\chi p} [\text{kg}^{-1} \text{ day}^{-1} \text{ keV}^{-1} \text{ fb}^{-1}]}$



Reconstruction: Inelastic Scattering



δ fixed during simulation,
allowed to vary during
reconstruction

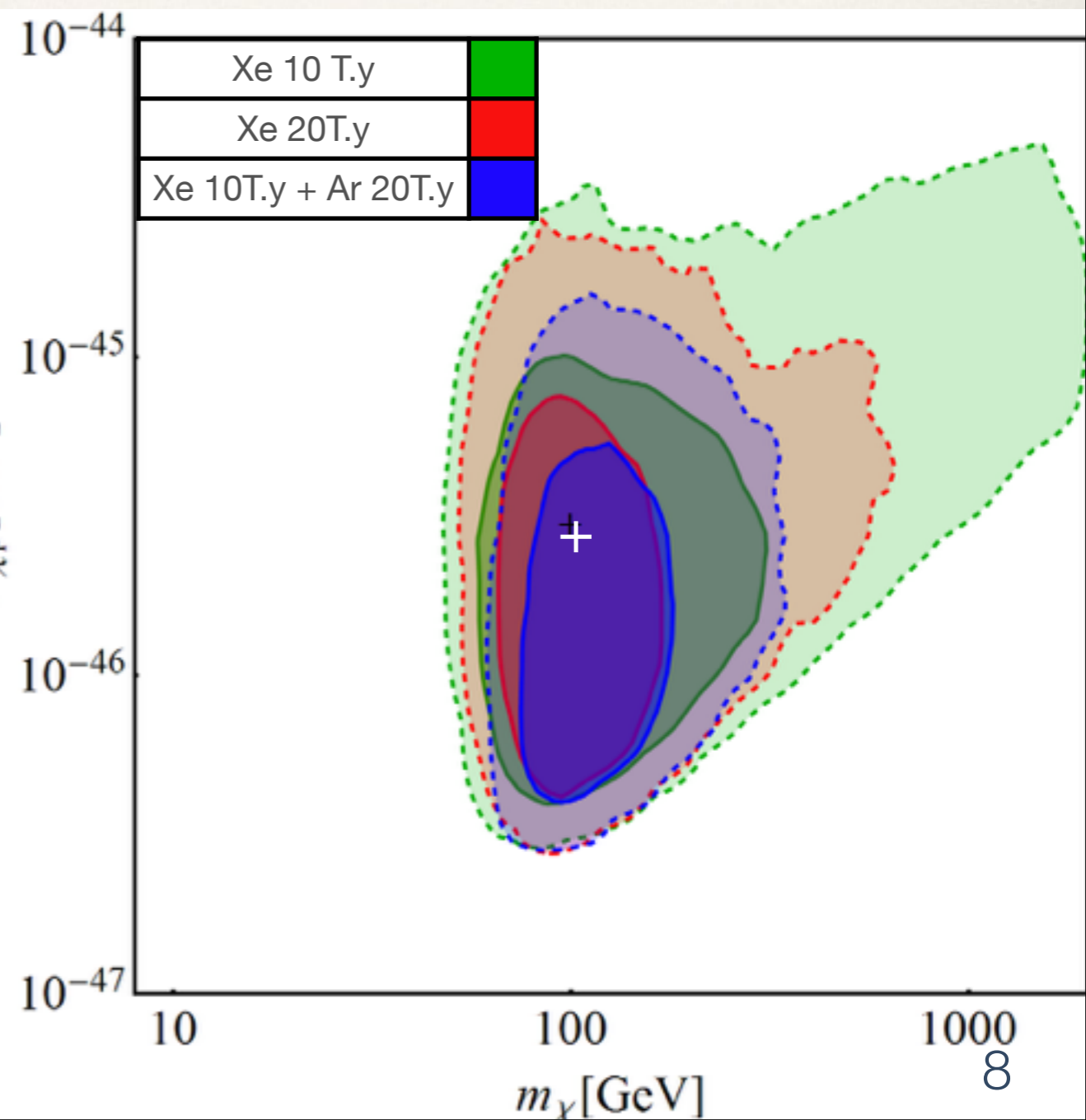
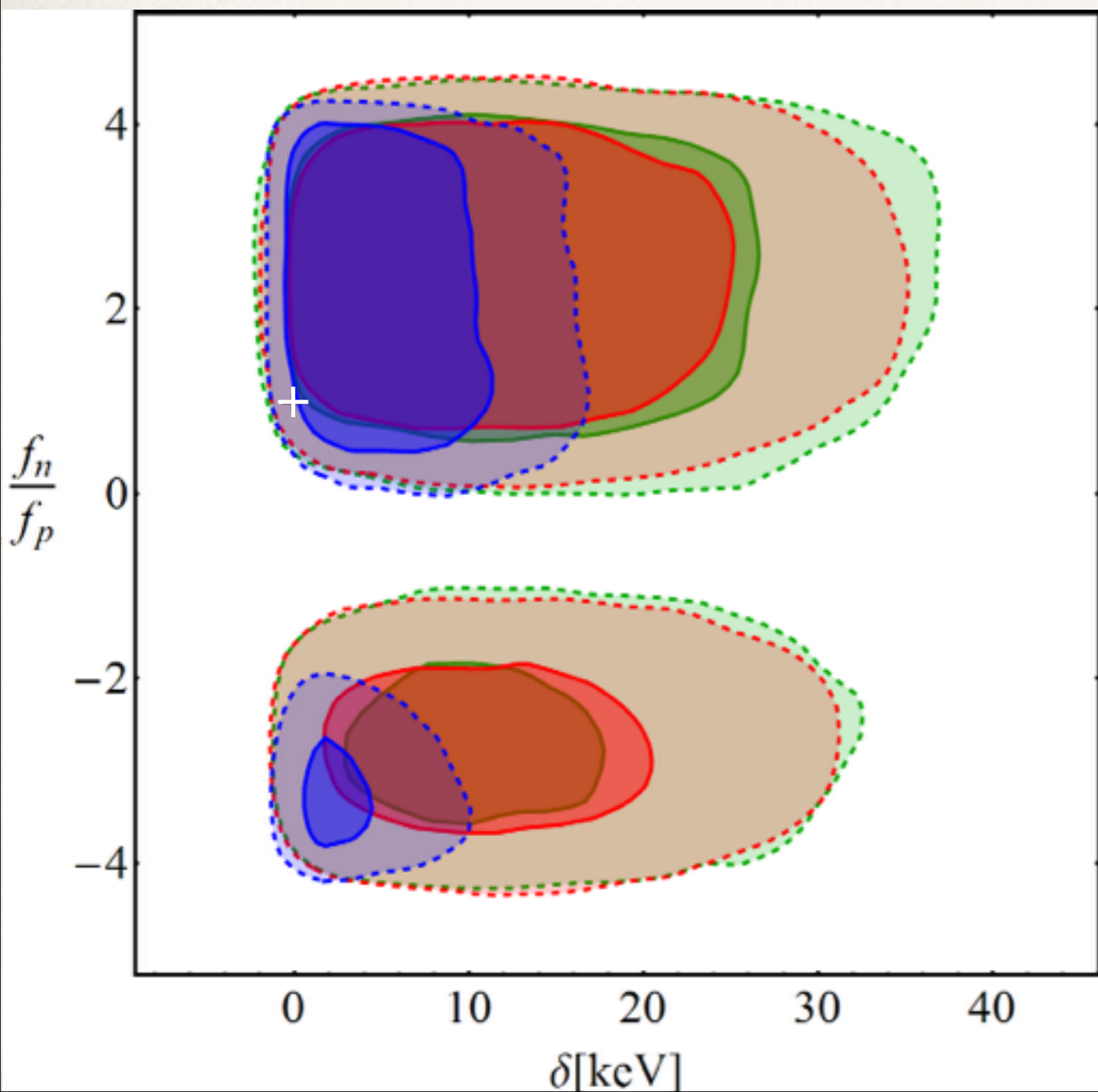
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Reconstruction: ISV + IES

$$\sigma_{SI} = 3 \times 10^{-46} \text{ cm}^2$$

$$m_\chi = 100 \text{ GeV}$$

- $f_n/f_p = 1$, $\delta = 0 \text{ keV}$ during simulation, both allowed to vary during reconstruction
- Strength of constraints severely weakened
- Constraints on δ stronger than on f_n/f_p

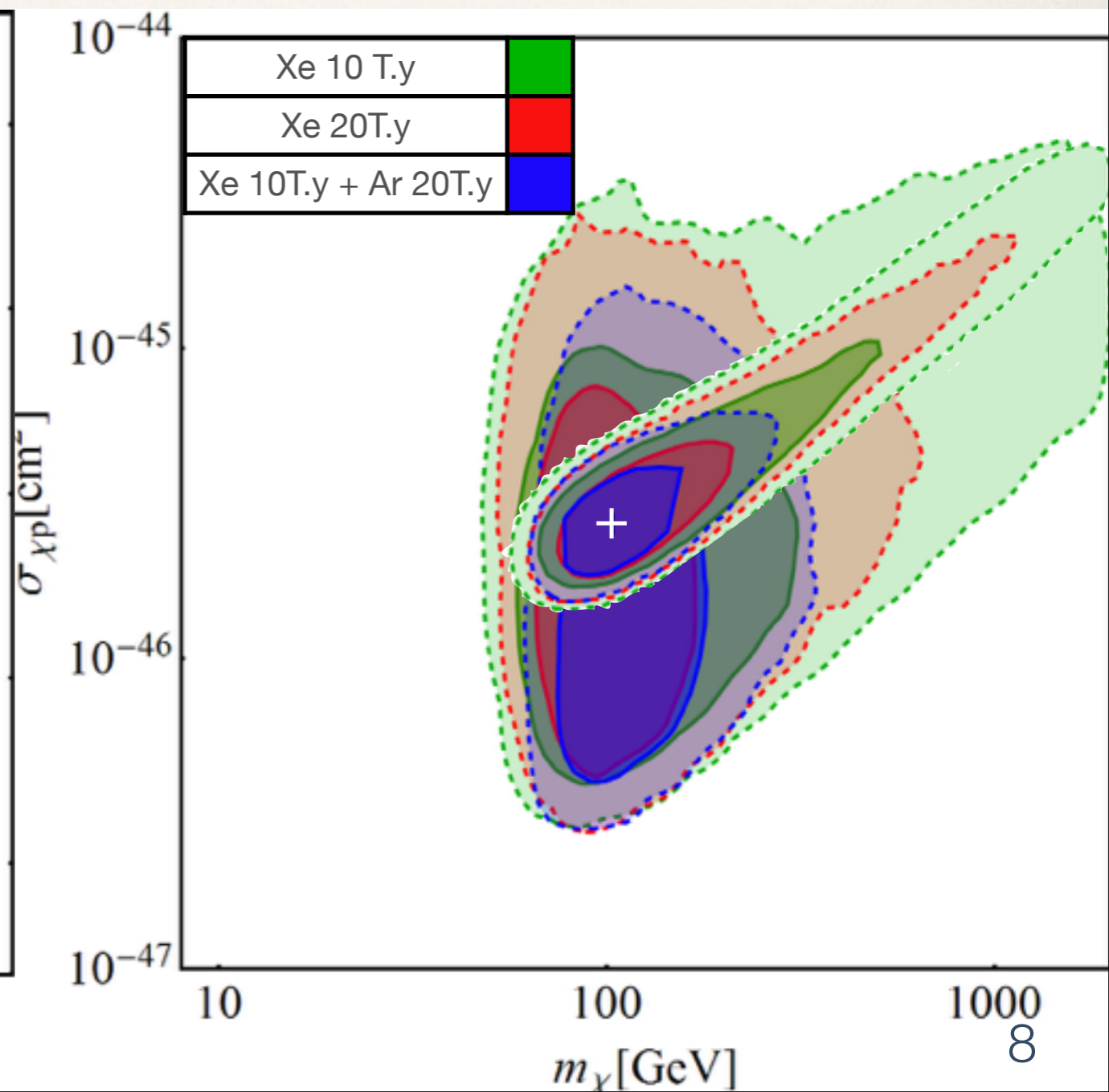
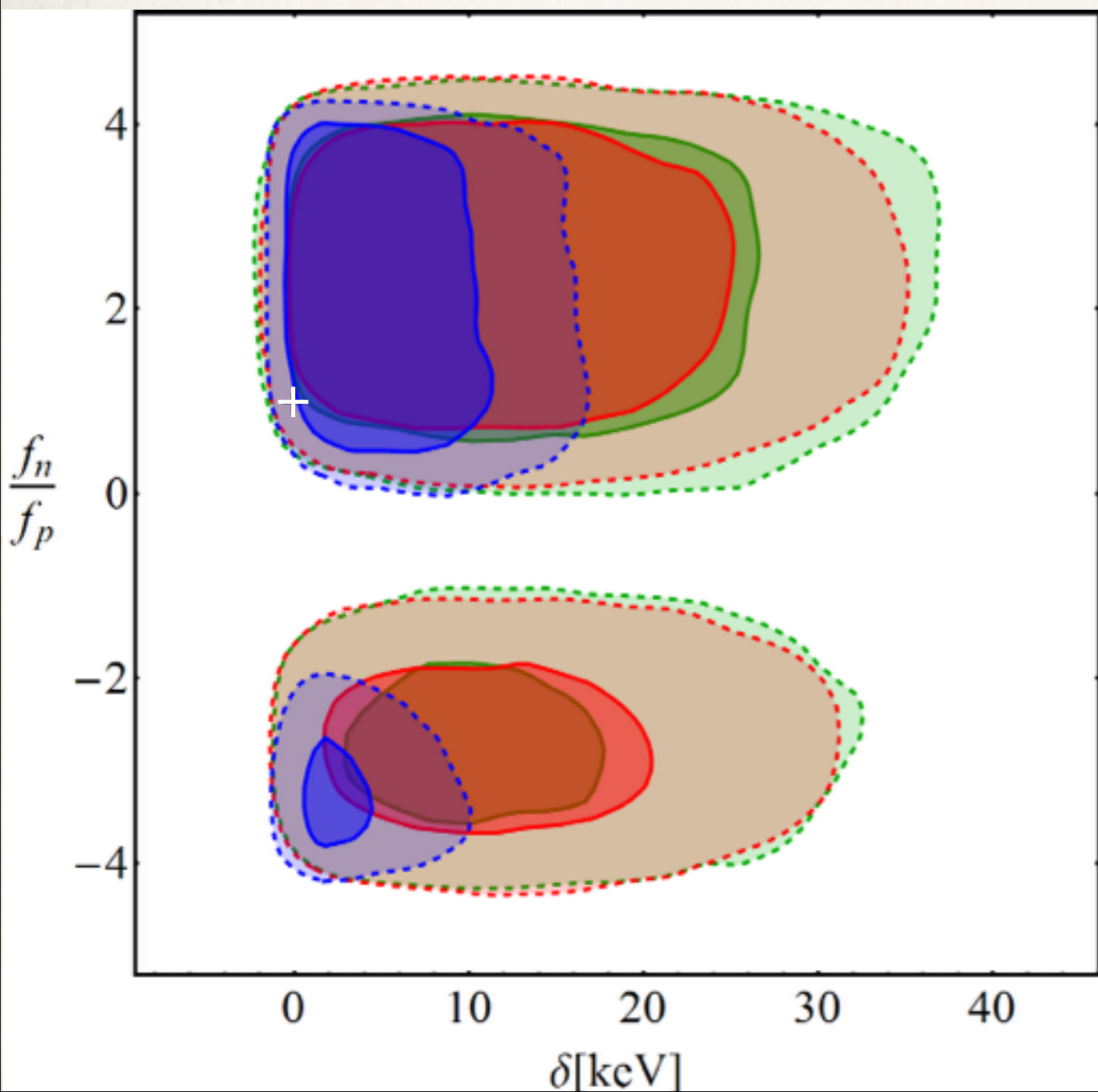


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Future Goals / Direction with our software tools

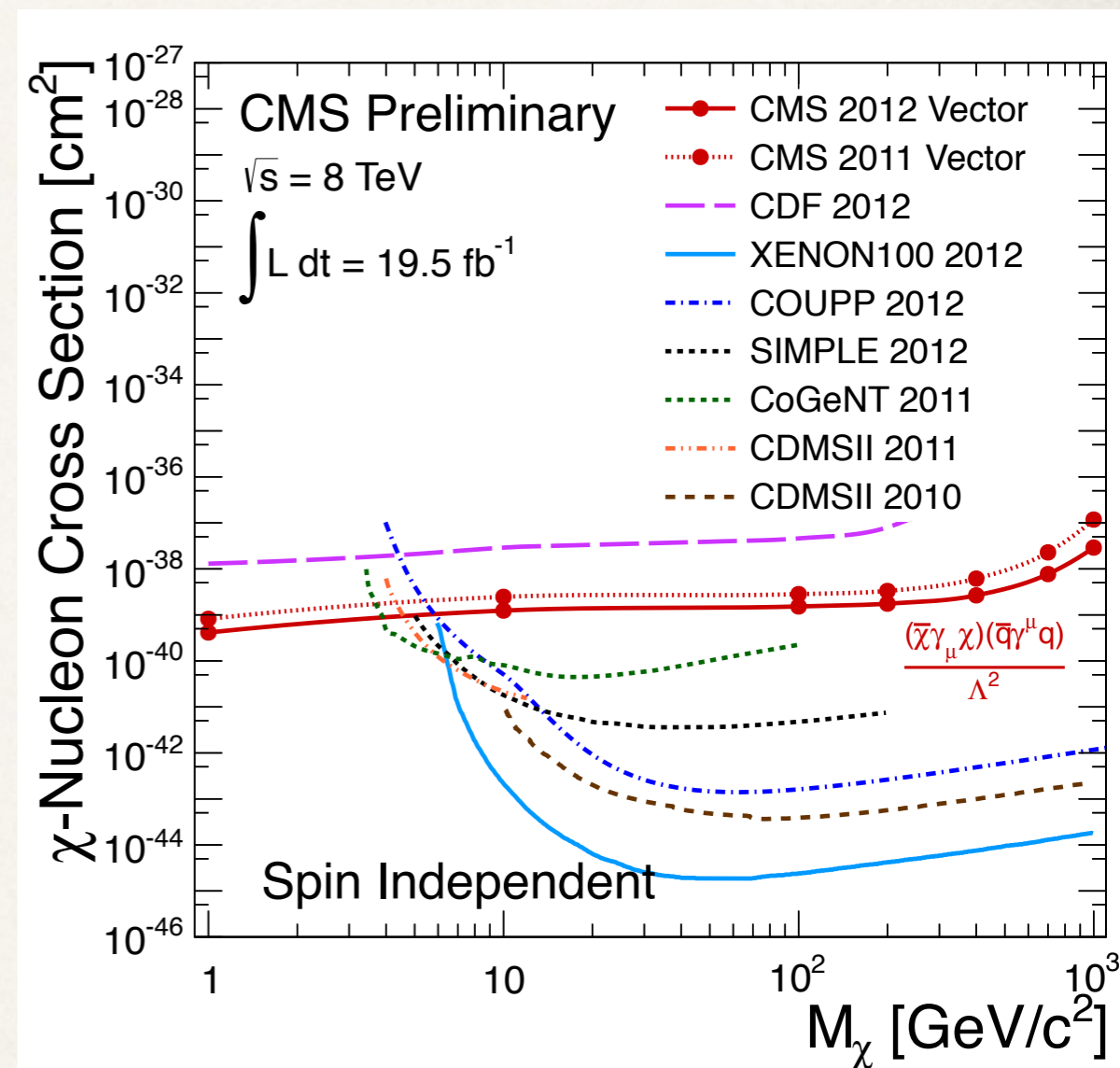
- Spin dependent scattering and annual modulation implemented but not tested
- Effect in Darwin of reconstructing DM parameters with incorrect assumptions
- More realistic detector information, ie energy resolution
- Upgrades to usability and interface
- Investigating implementation of choice of operator

Effective Field Theory

- Can we isolate the underlying operator? Many have fundamental degeneracies in the recoil spectrum, but not all
- Complementarity of direct detection and collider results to extract more information and eliminate degeneracies
- Particularly interesting are operators with mix of SI and SD interactions. Relative Xe, Ar event rates may be revealing, but we need to see how well-motivated these operators are

Confusion

- Difference in terminology between collider and direct detection groups:
- SI $\sim (\bar{\chi}\chi)(\bar{N}N)$
and SD $\sim (\bar{\chi}\gamma^\mu\gamma^5\chi)(\bar{N}\gamma_\mu\gamma^5N)$
are being compared to constraints on all operators...
- Can we clear this up for them?
- Especially important since the standard SI and SD operators give the strongest constraints



To summarise

- Dual targets reduces degeneracies and enhance discrimination, relative to increasing the exposure of either individual target.
- The effect is strongest for $m_\chi \approx 200\text{GeV}$
- Developing tools to further explore the extended WIMP space
- Extending to EFT analysis