Effective WIMPs

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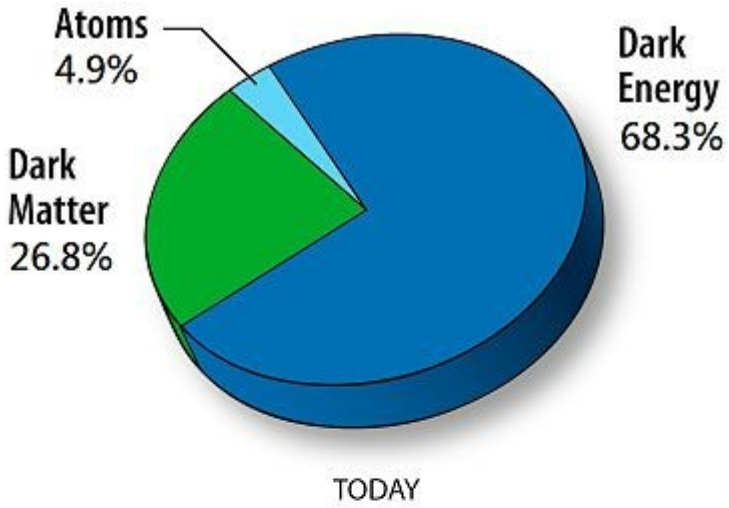
University of California, Davis

With
Spencer Chang, Ralph Edezhath, & Markus Luty

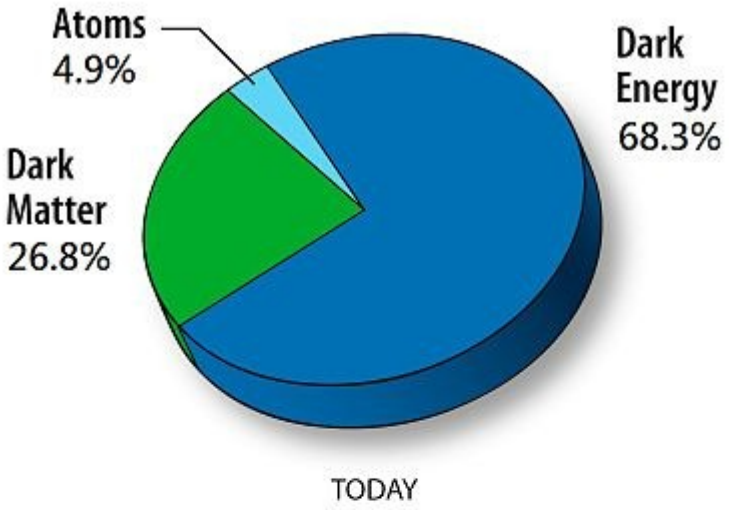
Based on: arXiv:1307.8120

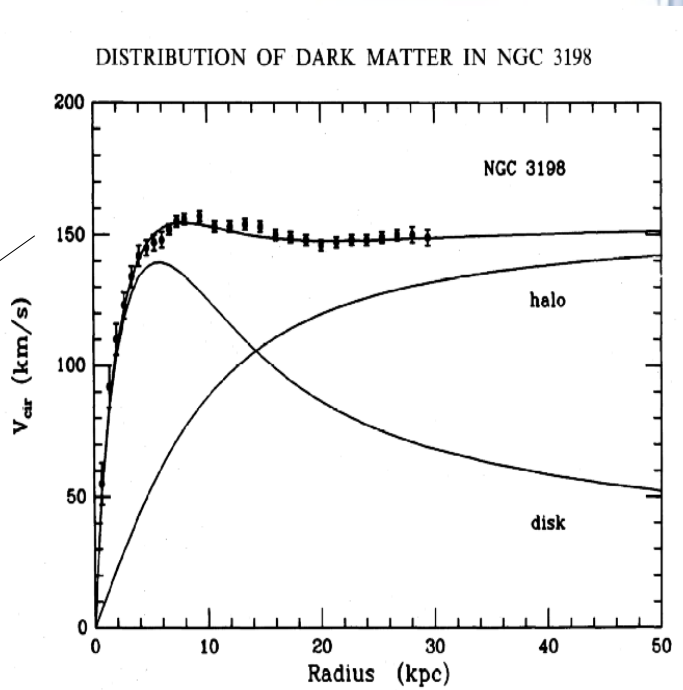
Dark Matter



Galactic Rotation Curves

Dark Matter





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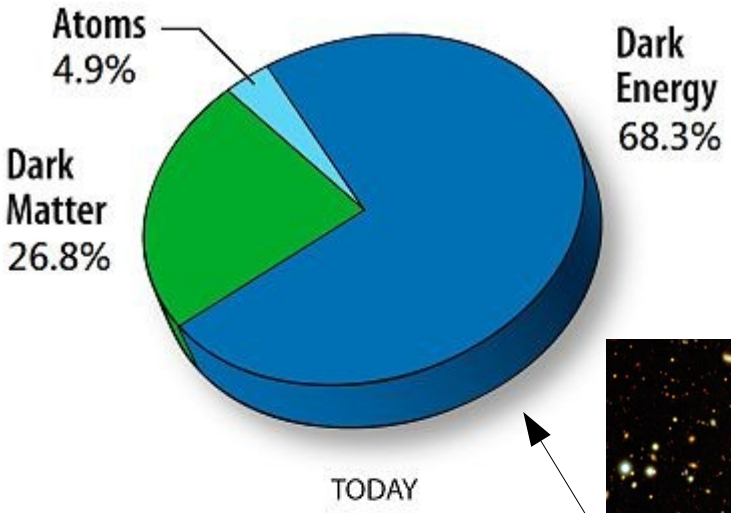
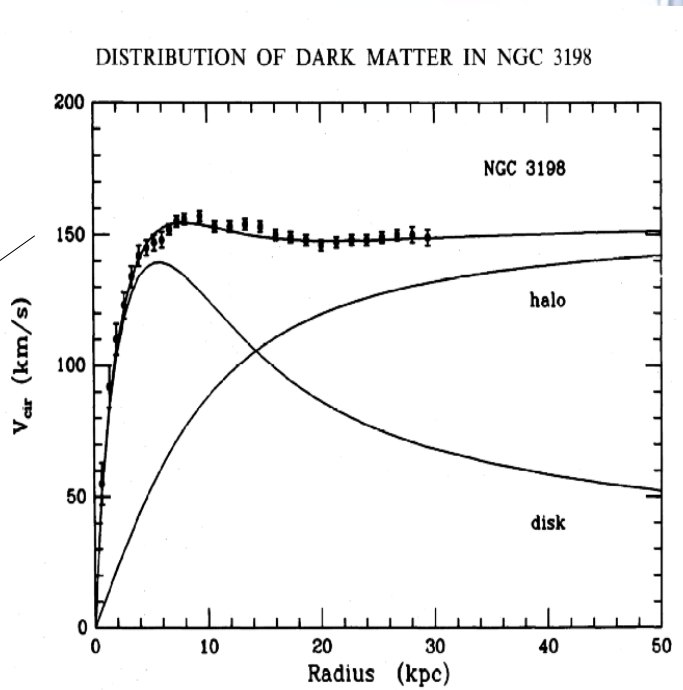
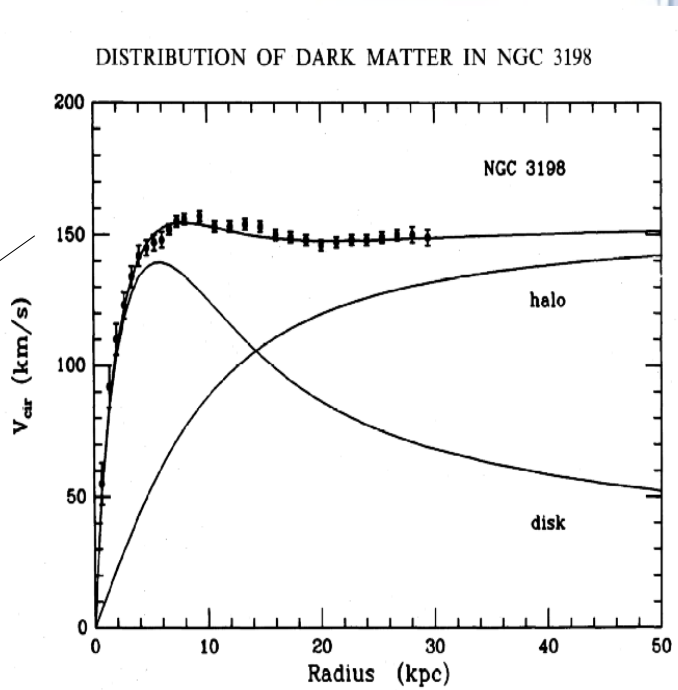


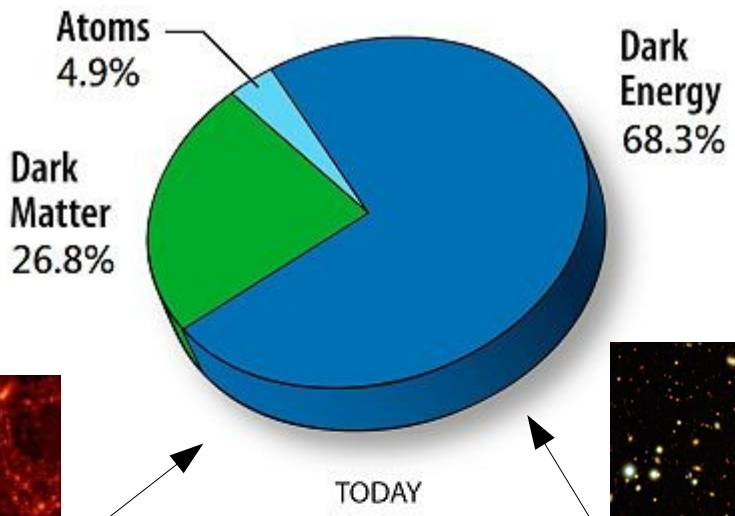


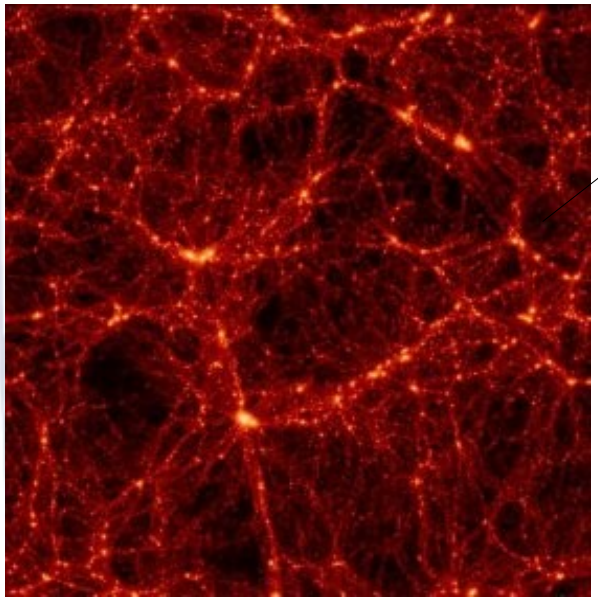
Weak Lensing

Dark Matter

Galactic Rotation Curves





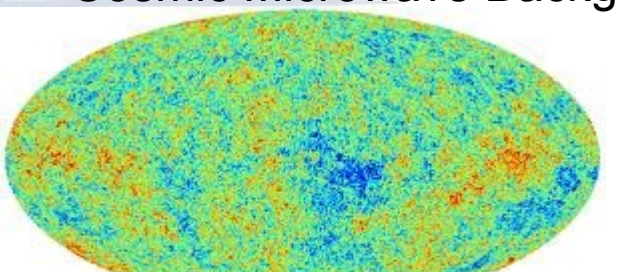


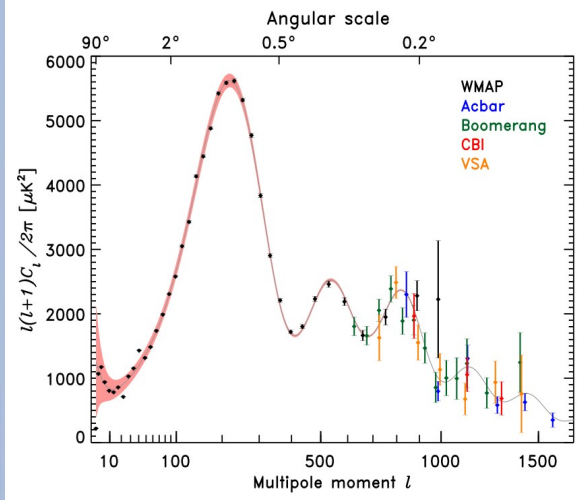
Large Scale Structure Formation

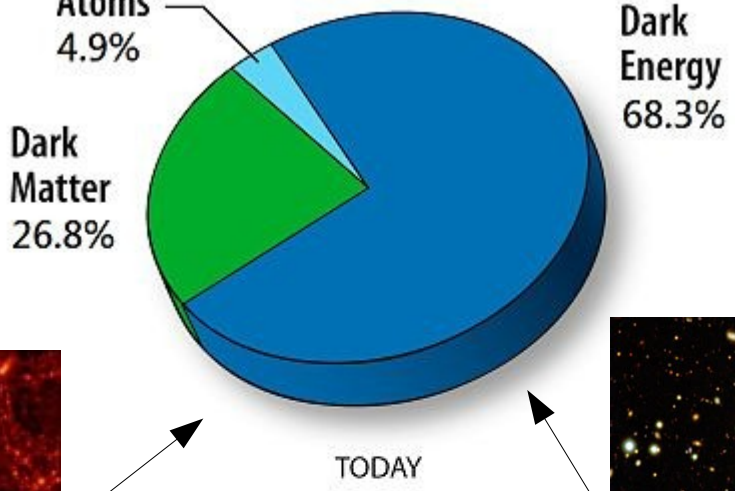
Weak Lensing

Dark Matter

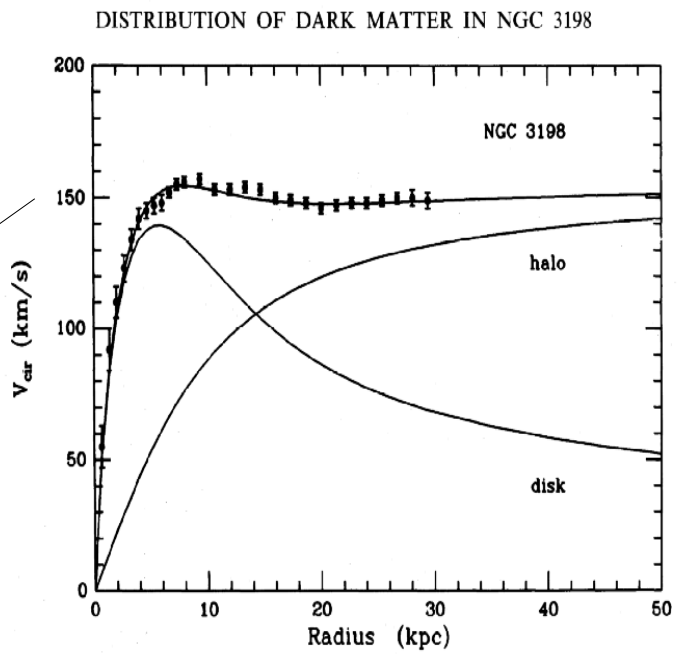
Cosmic Microwave Background

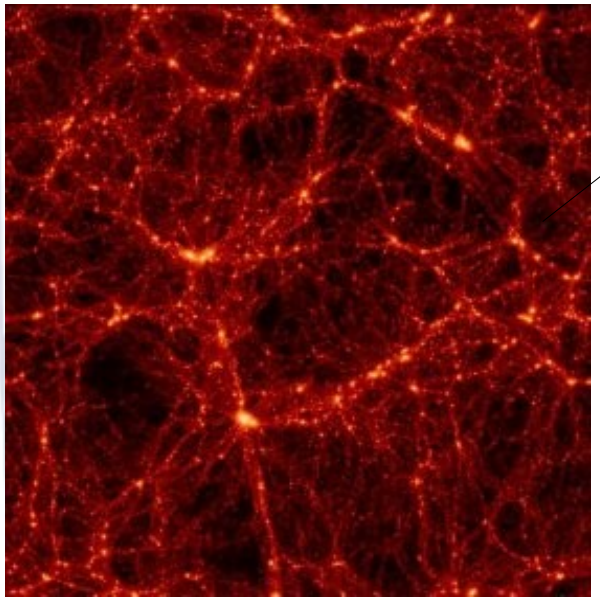






Galactic Rotation Curves





Large Scale Structure Formation

Weak Lensing

WIMPs

WIMP = “Weakly Interacting Massive Particle”

WIMPs

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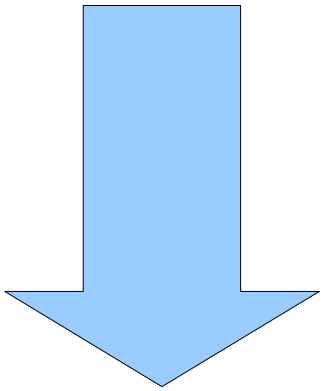
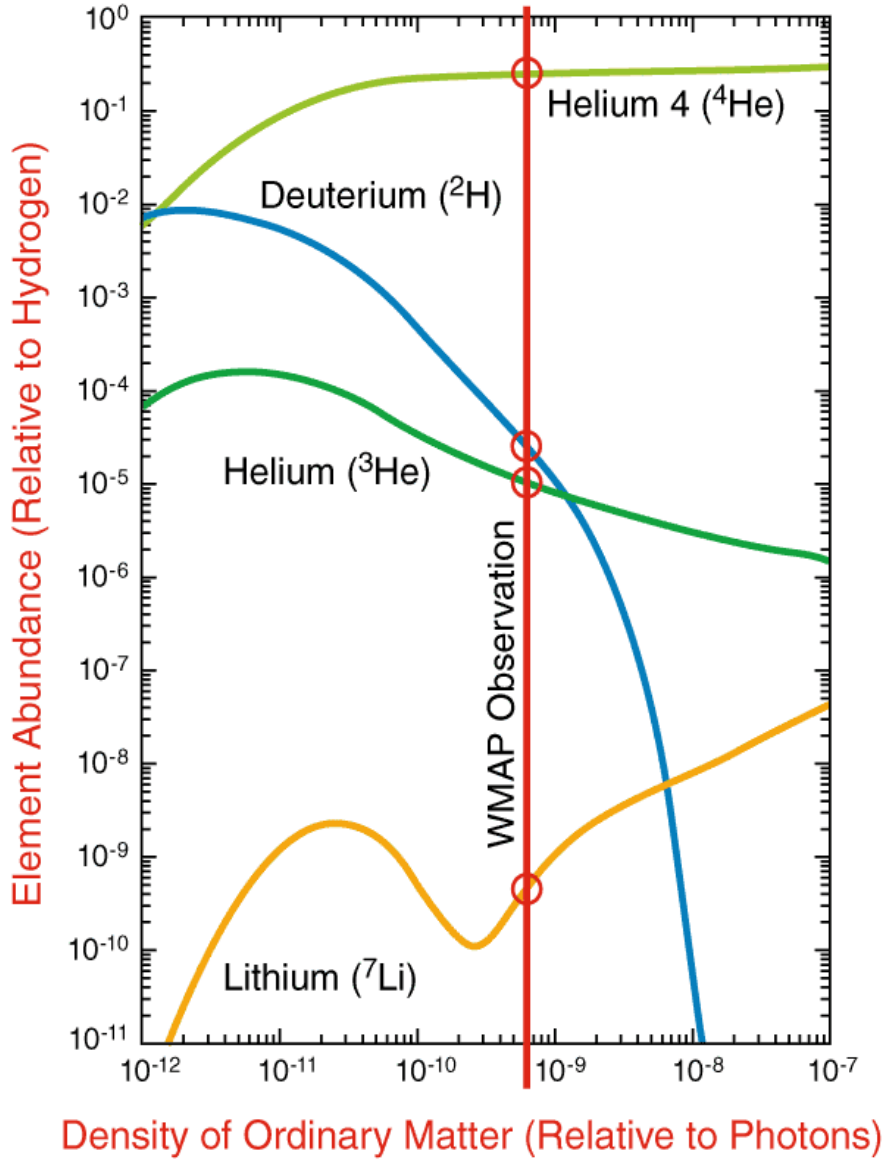


New Particles

Why WIMPs?

Too much Baryonic Matter

Wrong Primordial Abundances

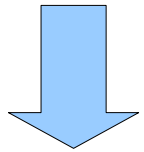


NASA/WMAP Science Team
WMAP101087

Element Abundance graphs: Steigman, Encyclopedia of Astronomy and Astrophysics (Institute of Physics) December, 2000

Why WIMPs?

Too much Baryonic Matter

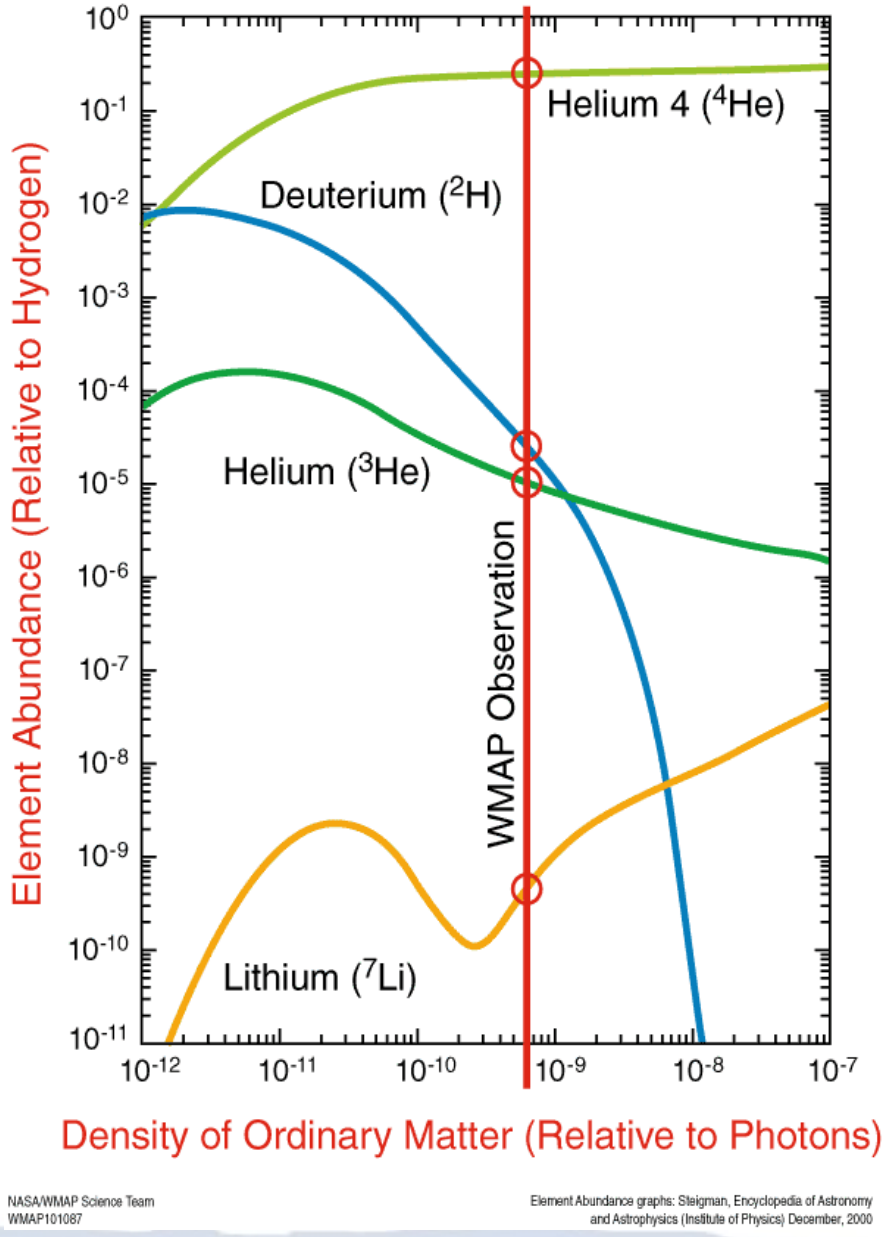


Wrong Primordial Abundances

Not:

Black Holes &

Non-Luminous Baryonic Matter



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Why WIMPs?

"WIMP Miracle"

Weak Scale Mass (~100GeV)

+

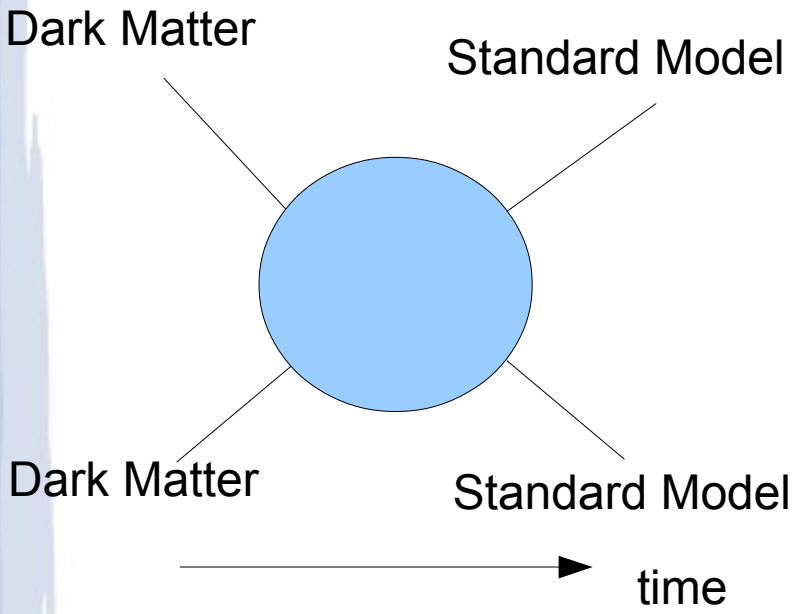
Weak Scale Coupling (~0.1)

~

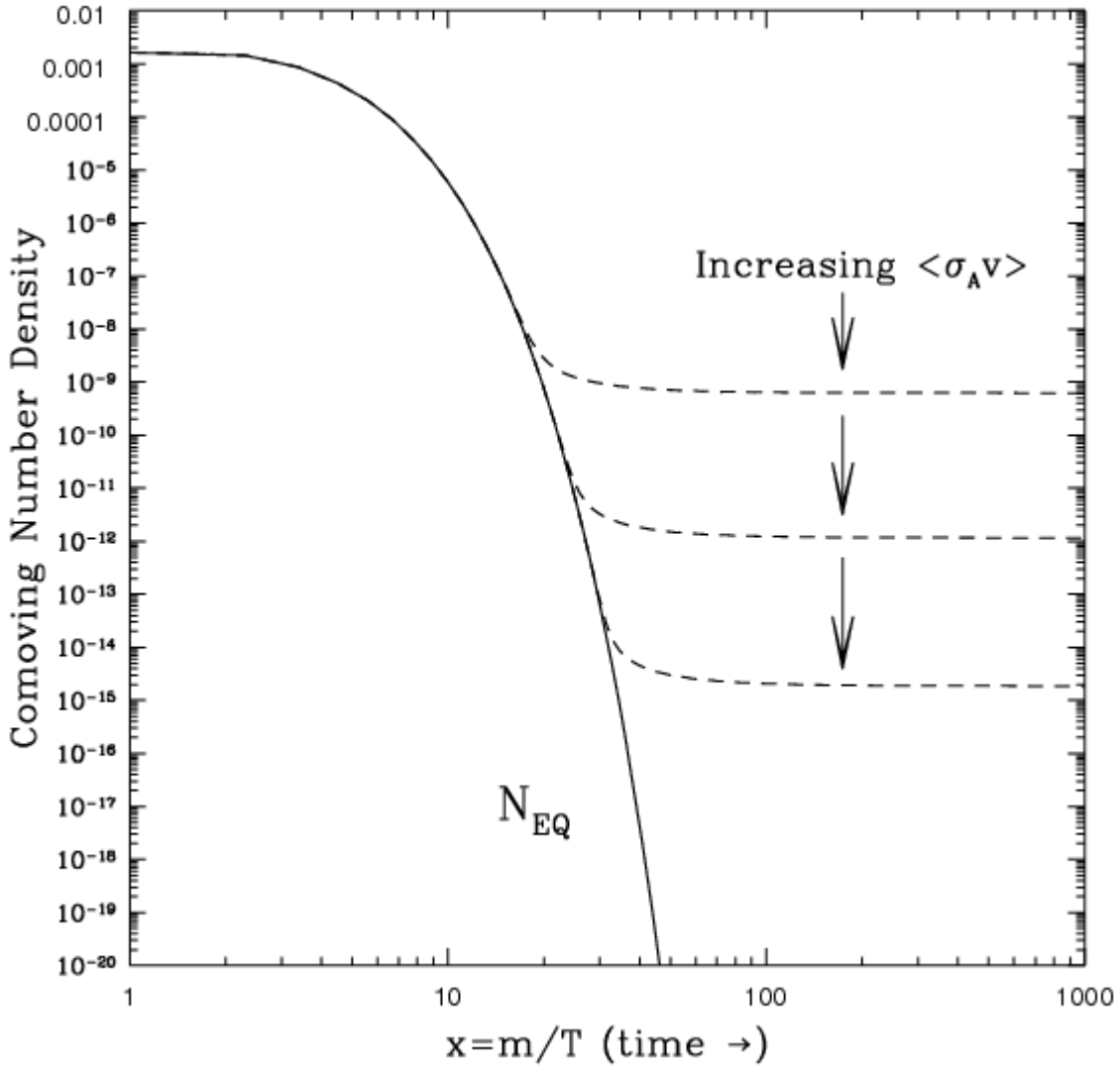
Correct Abundance

Relic Abundance

Thermal Relics



$$DM + DM \Leftrightarrow SM + SM$$



Dark Matter Searches

1) Collider

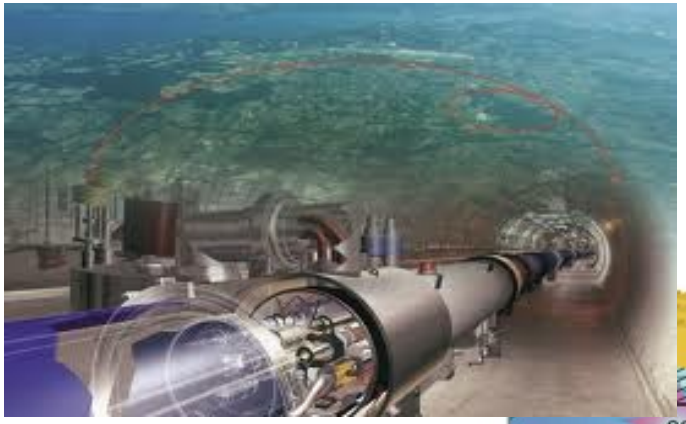
Make Dark Matter

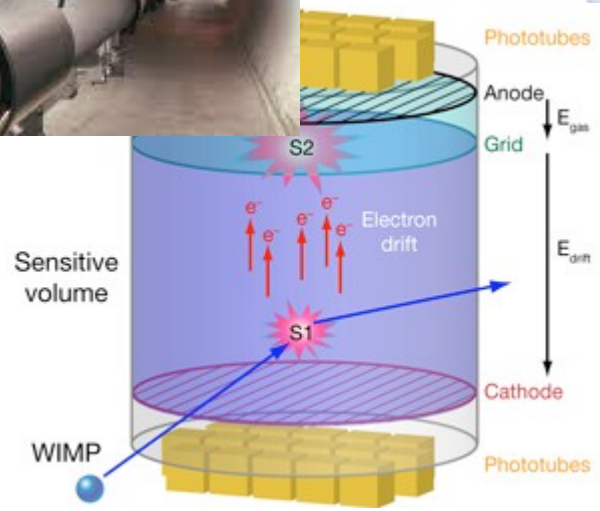
2) Direct Detection

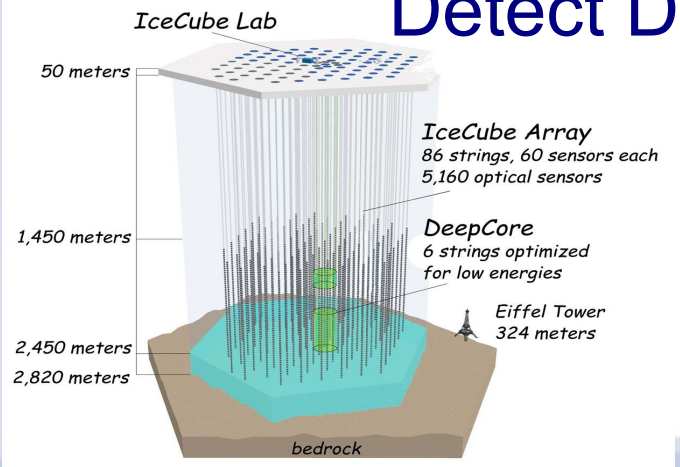
Detect Local Dark Matter

3) Indirect Detection

Detect Distant Dark Matter Annihilations

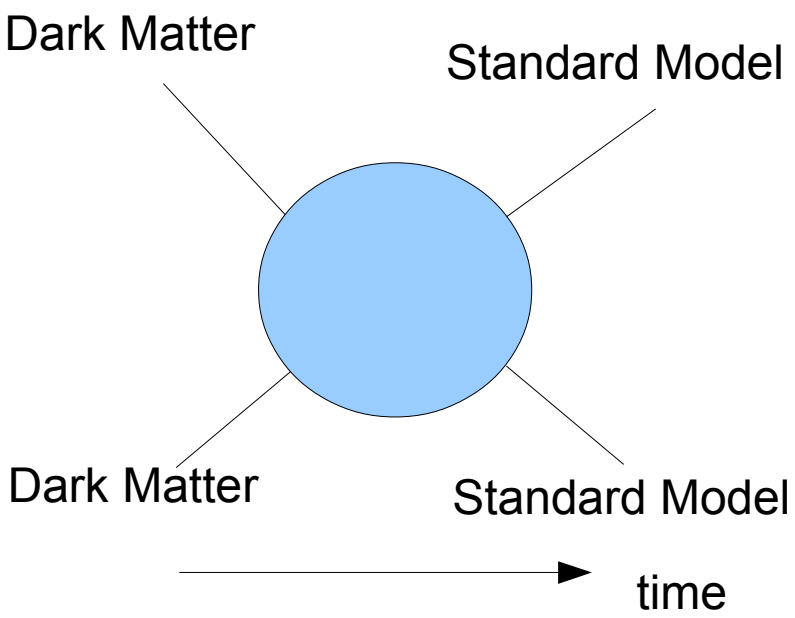






Indirect Detection

Dark Matter Annihilations



Same Basic Process

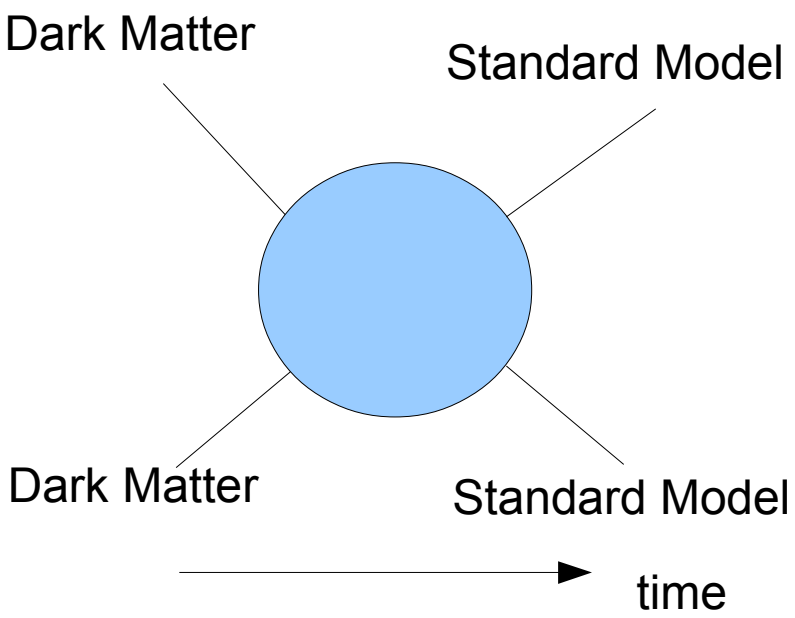
For Relic Abundance

Not Yet Sensitive

To Thermal Relics

Indirect Detection

Dark Matter Annihilations



Same Basic Process

For Relic Abundance

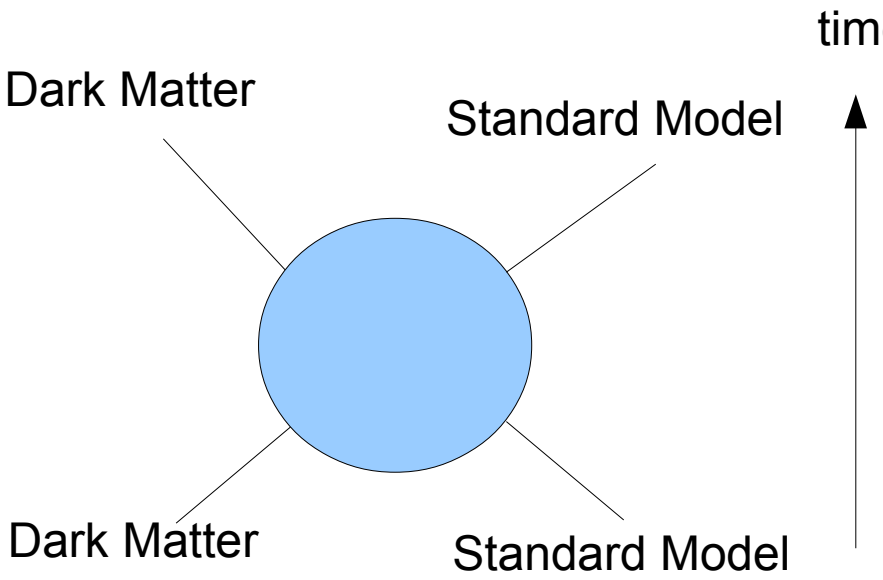
Not Yet Sensitive

To Thermal Relics

Not Relevant

Direct Detection

Dark Matter – Nuclei Collisions



Spin Dependent:

Amplitude ~ Spin

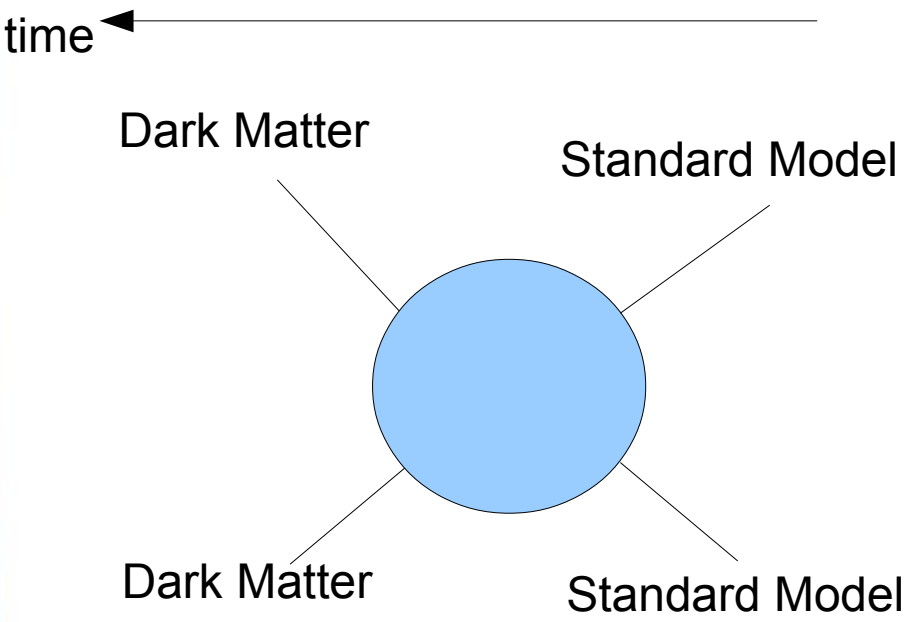
Spin Independent:

Amplitude Not~ Spin

Cross Section ~ A^2

Collider Searches

Dark Matter Production



Dark Matter

=

Missing Energy (MET)

Monojet

(1 quark/gluon + MET)

&

Jets + MET

(2 quark/gluon + MET)

Dark Matter Searches

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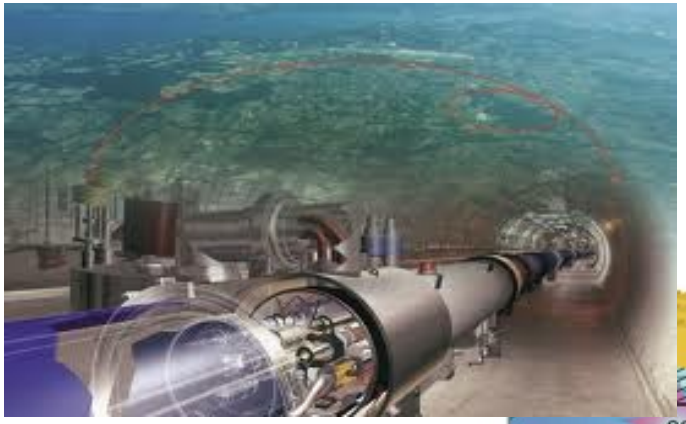
Make Dark Matter

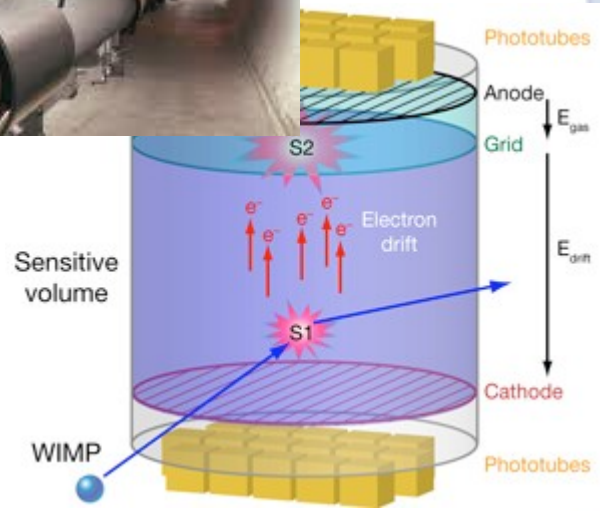
2) Direct Detection

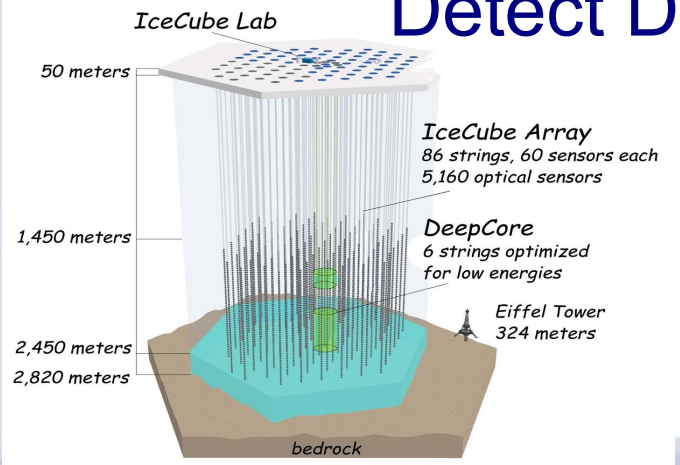
Detect Local Dark Matter

3) Indirect Detection

Detect Distant Dark Matter Annihilations







Our Models: Motivations

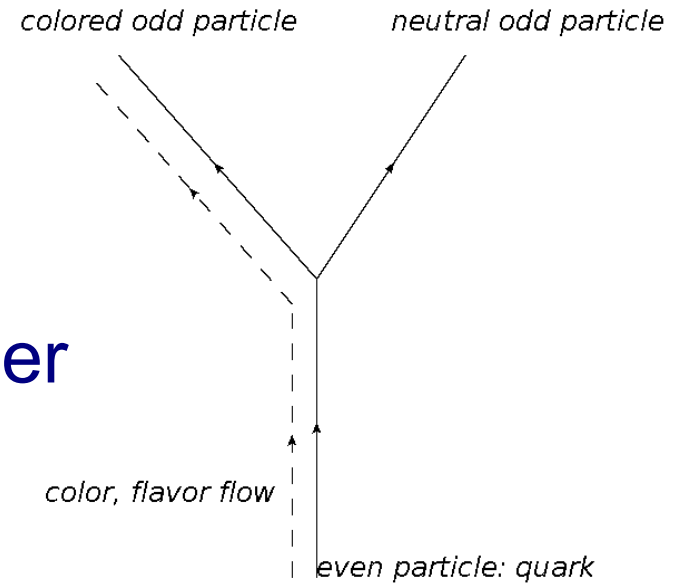
- Preserve “WIMP Miracle”
  - Thermal Relic DM
  - Renormalizable Interactions
- Minimal New Content
- Generality
  - All Spin Combinations
  - Own Antiparticle vs. Not
  - Flavor Structures

Our Models: Basics

2 New Particles:

- χ, Dark Matter
- Q, Standard Model Partner

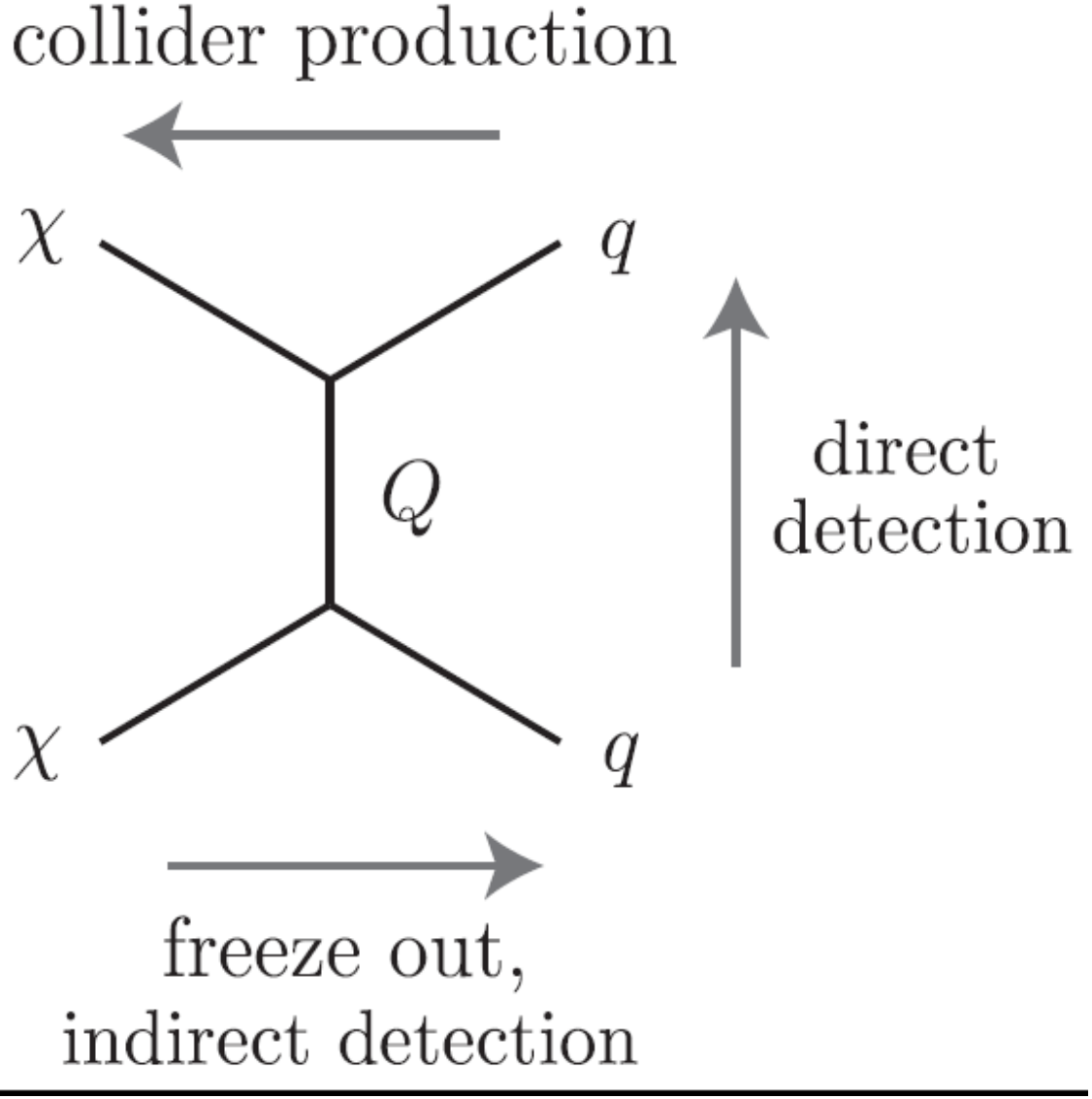
1 New Interaction, λ



3 Parameters → 2 Parameters

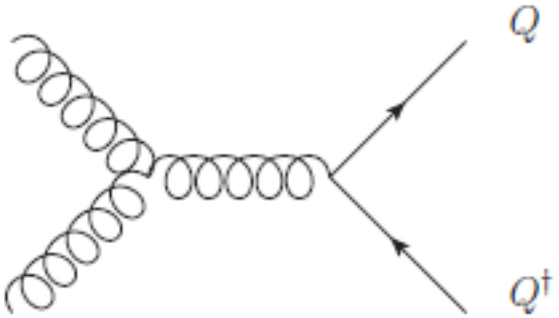
Relic Abundance

Basic Processes

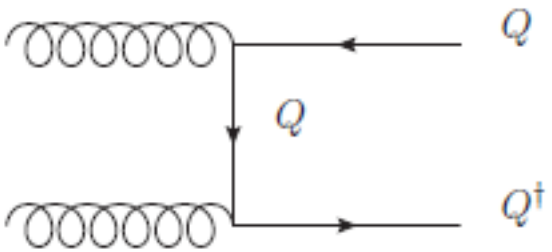


Collider Production

Jets+MET Production



$\sim g_s^2$



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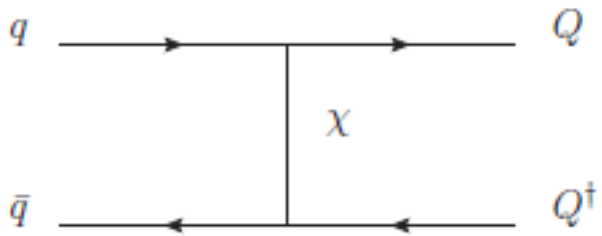
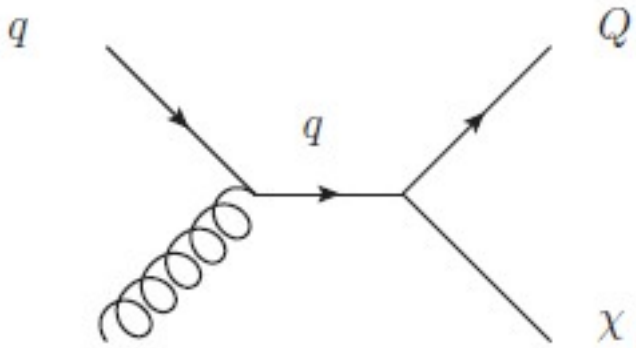
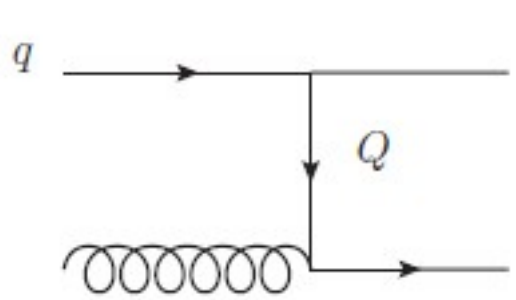


$\sim |\lambda|^2$

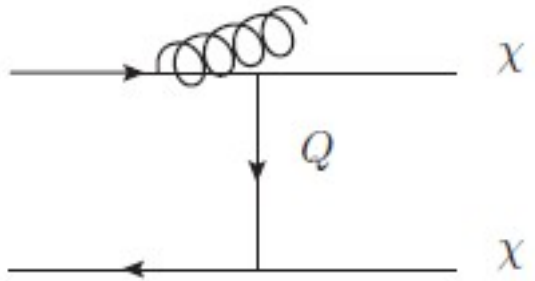
Monojet Production



$\sim g_s\lambda$



$\sim g_s\lambda$



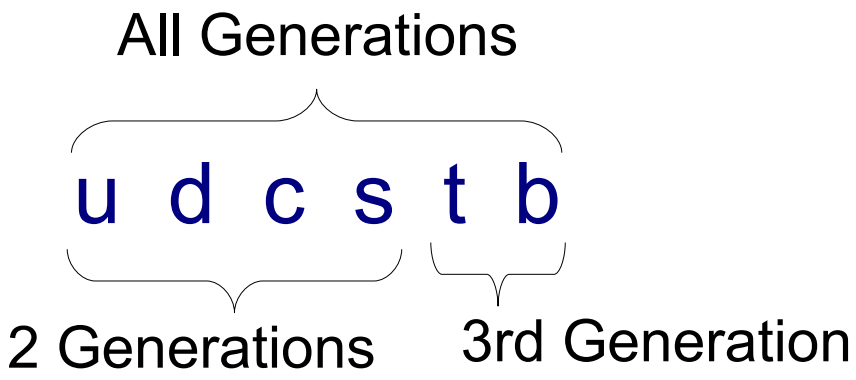
$\sim g_s|\lambda|^2$

Our Model: Variations

Spin	0	1/2	1
Own Antiparticle	χ: Real Scalar Q: Dirac Fermion	χ: Majorana Fermion Q: Complex Scalar	χ: Real Vector Q: Dirac Fermion
Not Own Antiparticle	χ: Complex Scalar Q: Dirac Fermion	χ: Dirac Fermion Q: Complex Scalar	χ: Complex Vector Q: Dirac Fermion

SM Particle = Quarks

3 Flavor Variations:



Our Model: Basic Features

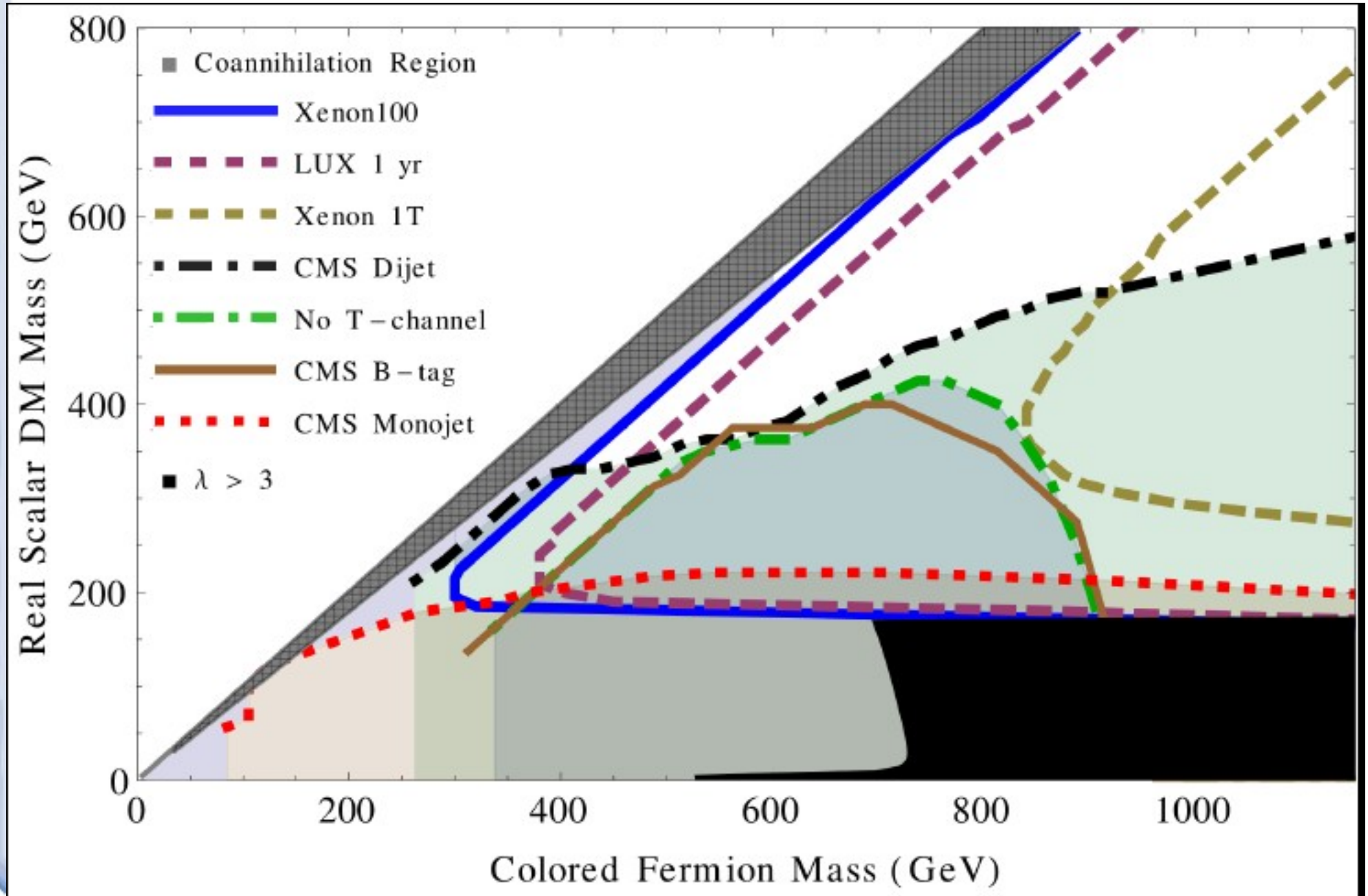
Enhanced Direct Detection Near Degeneracy

Larger λ Extends Limits to Larger m_Q

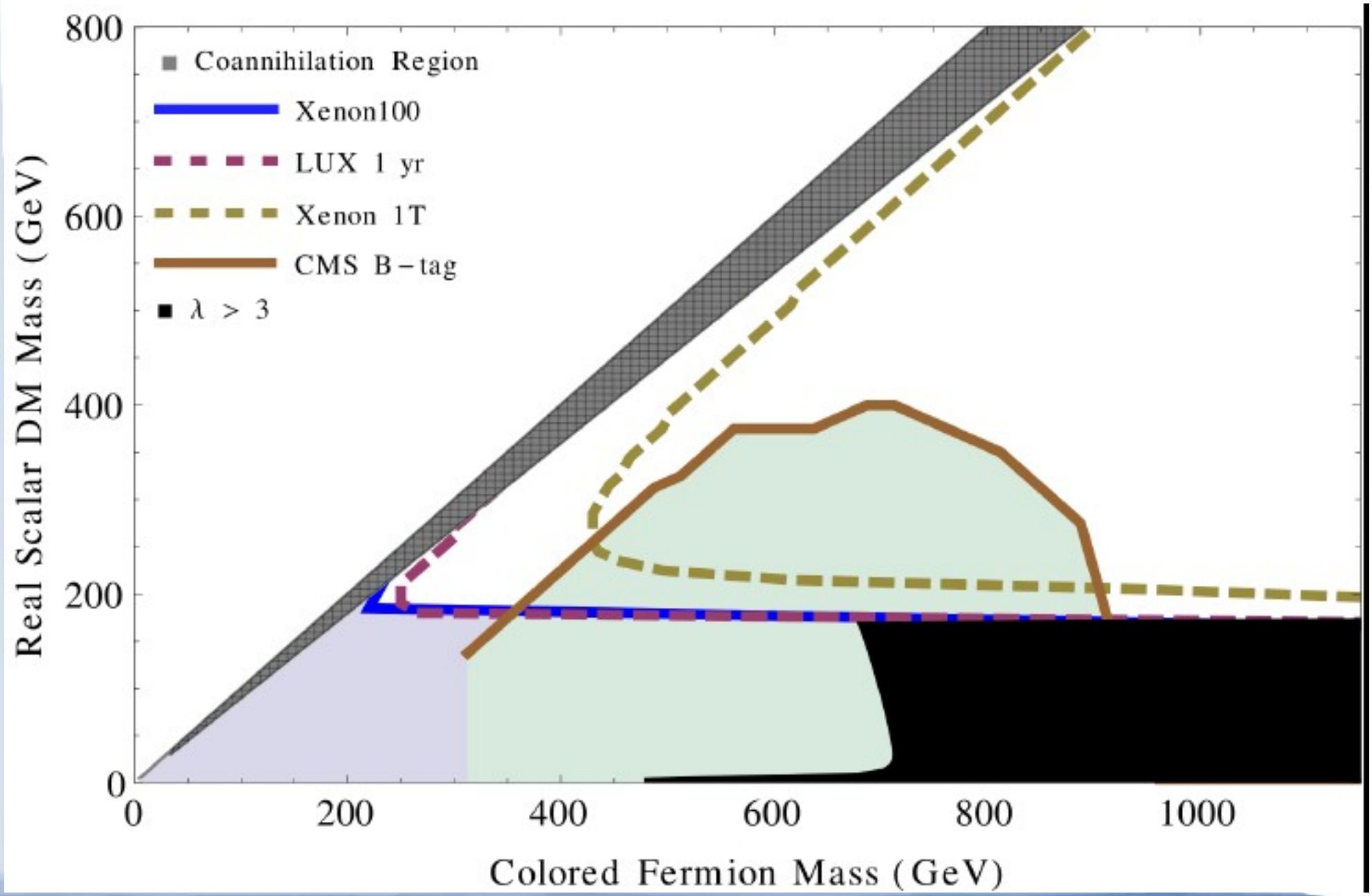
Direct Detection Rules Out:

Spin	0	1/2	1
Own Antiparticle	χ: Real Scalar Q: Dirac Fermion	χ: Majorana Fermion Q: Complex Scalar	χ: Real Vector Q: Dirac Fermion
Not Own Antiparticle	χ: Complex Scalar Q: Dirac Fermion	χ: Dirac Fermion Q: Complex Scalar	χ: Complex Vector Q: Dirac Fermion

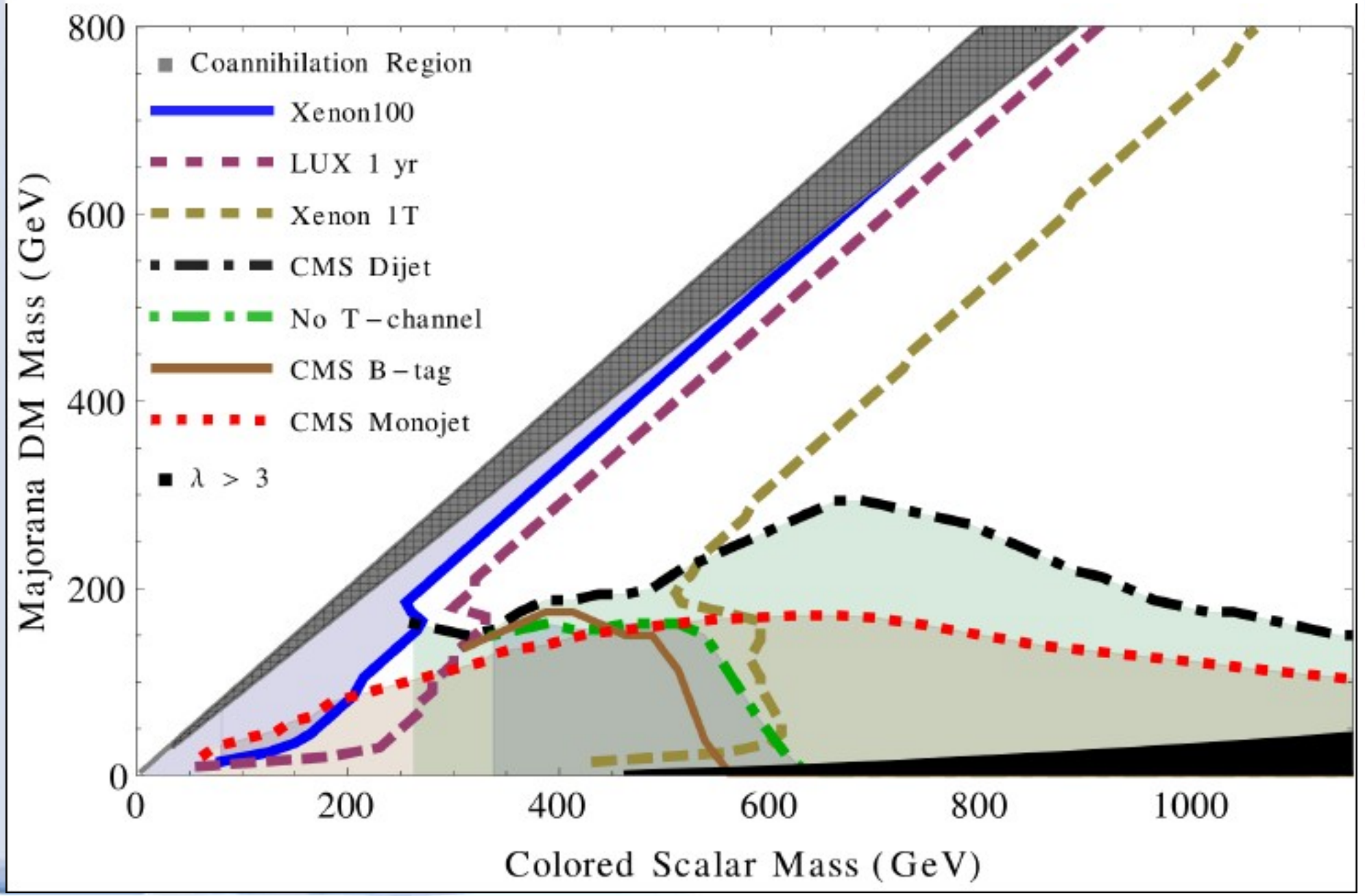
Real Scalar Dark Matter (All Gen.)



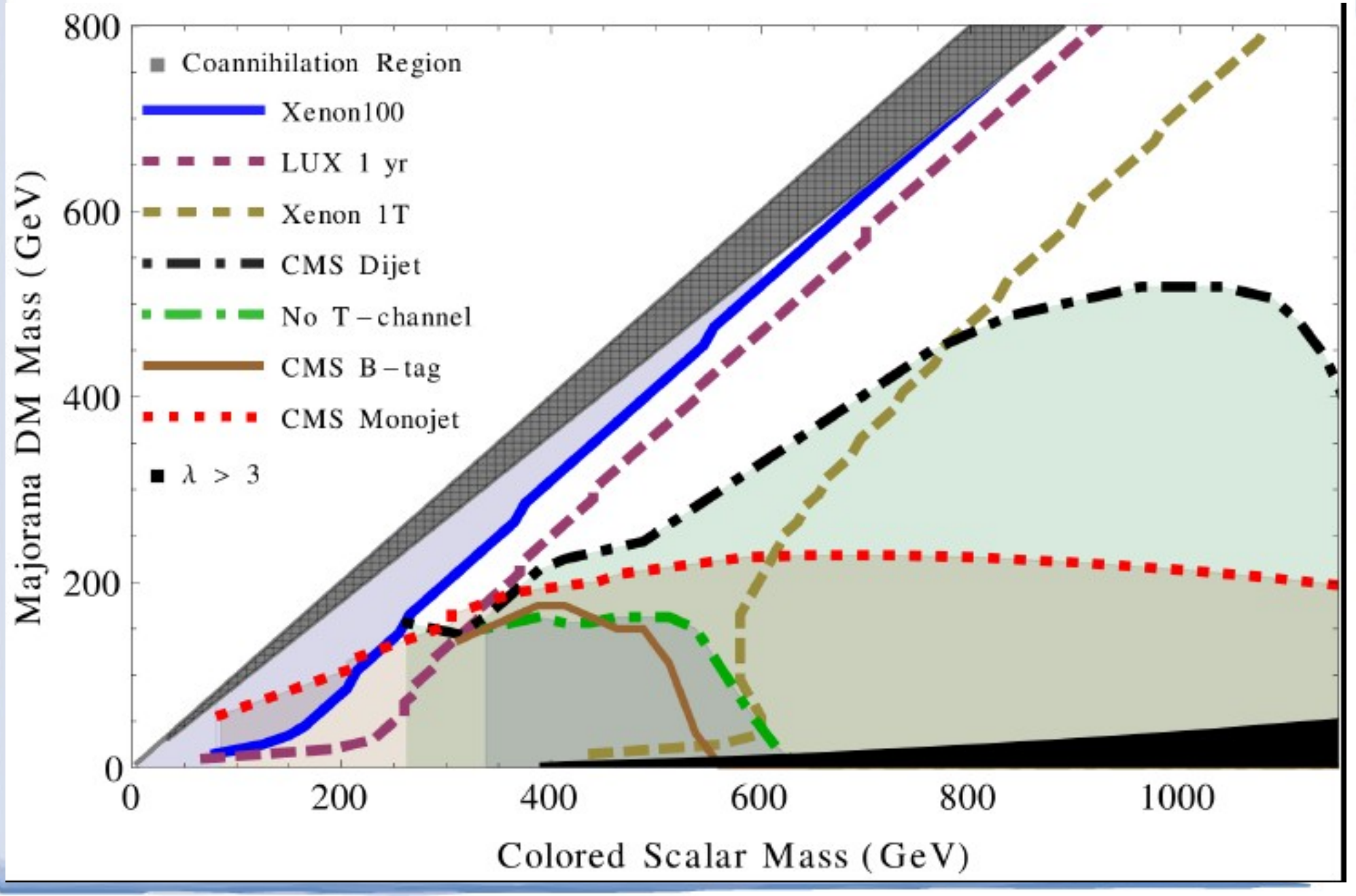
Real Scalar Dark Matter (3rd Gen.)



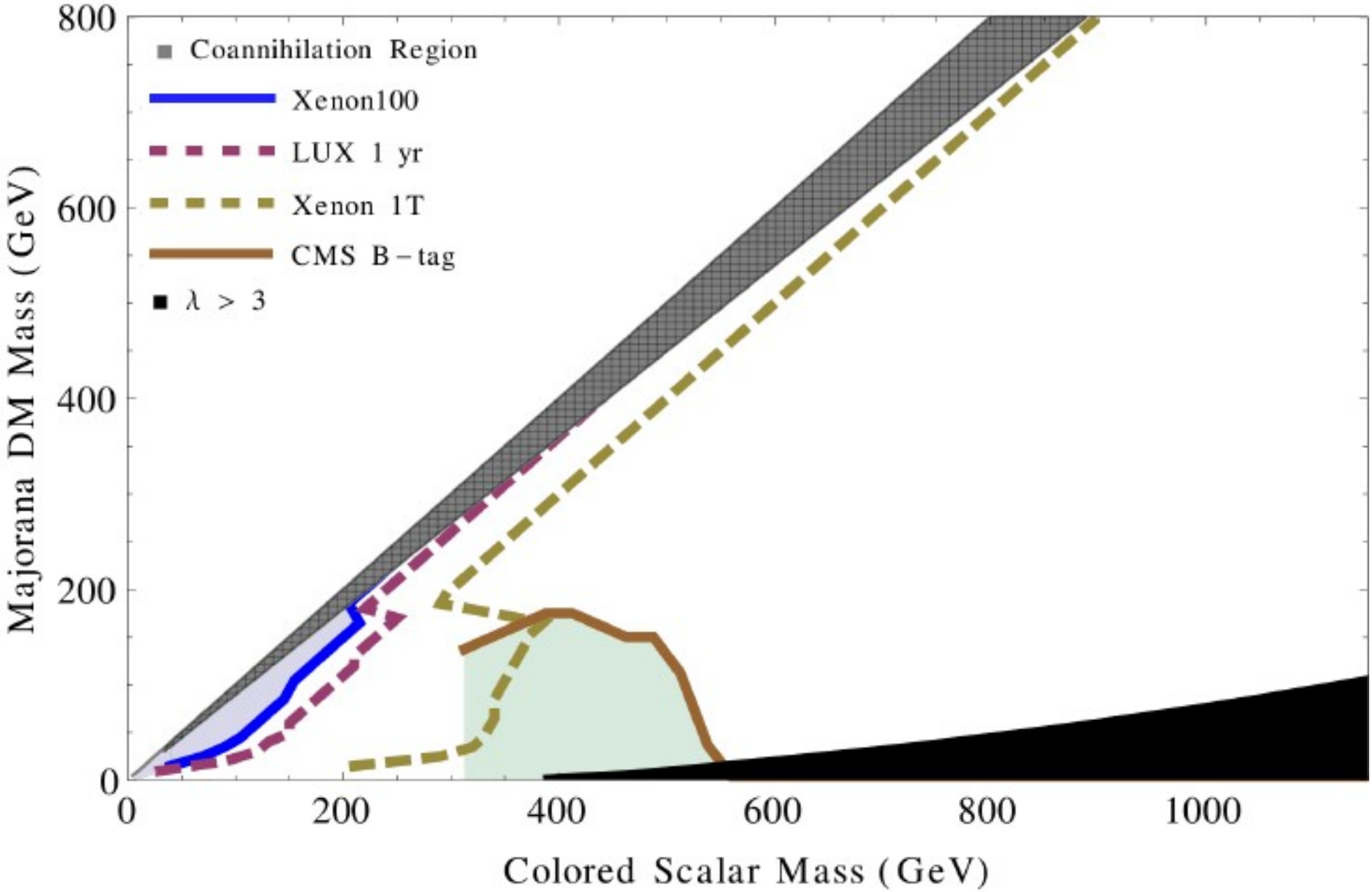
Majorana Dark Matter (All Gen.)



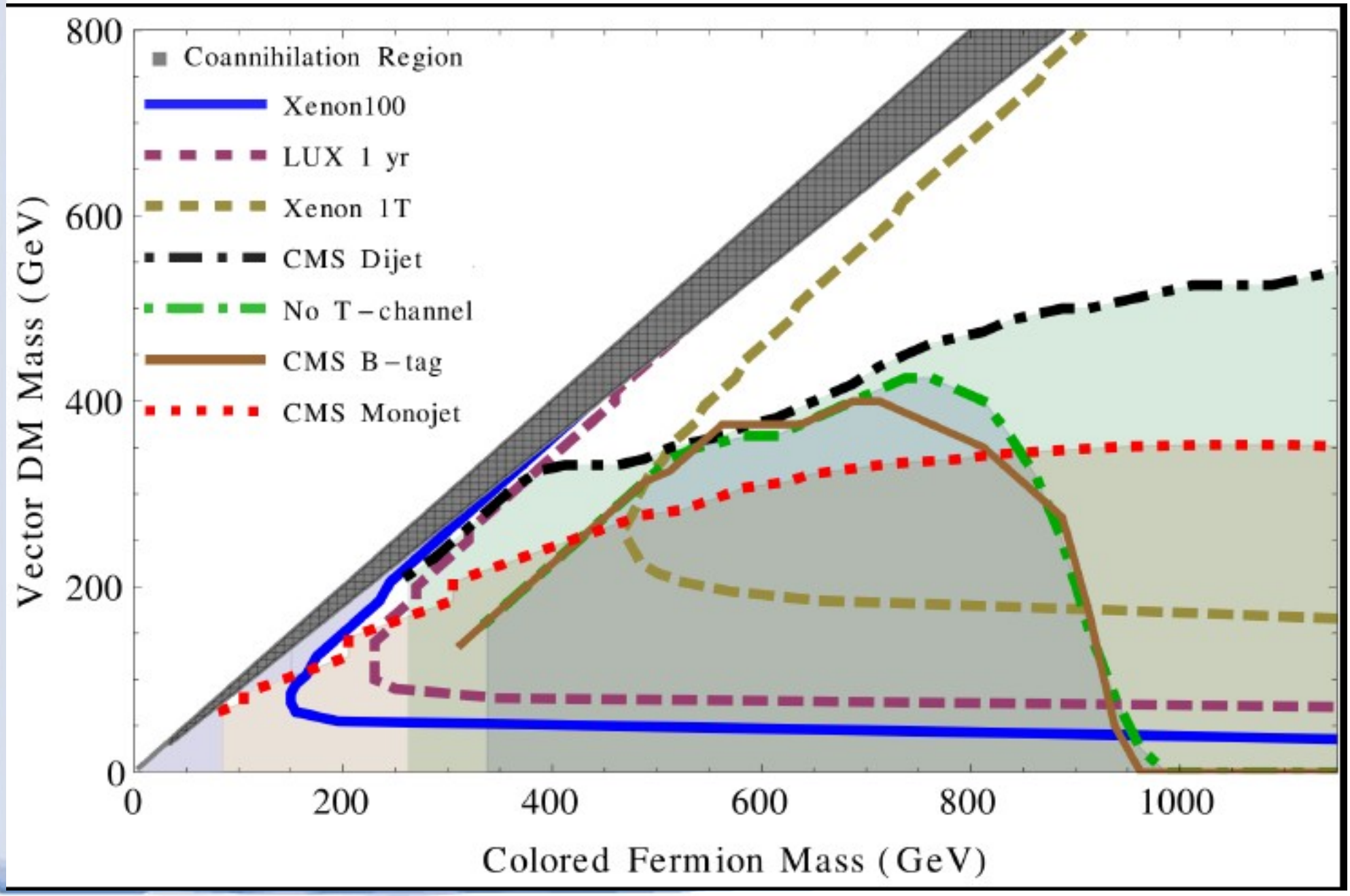
Majorana Dark Matter (2 Gen.)



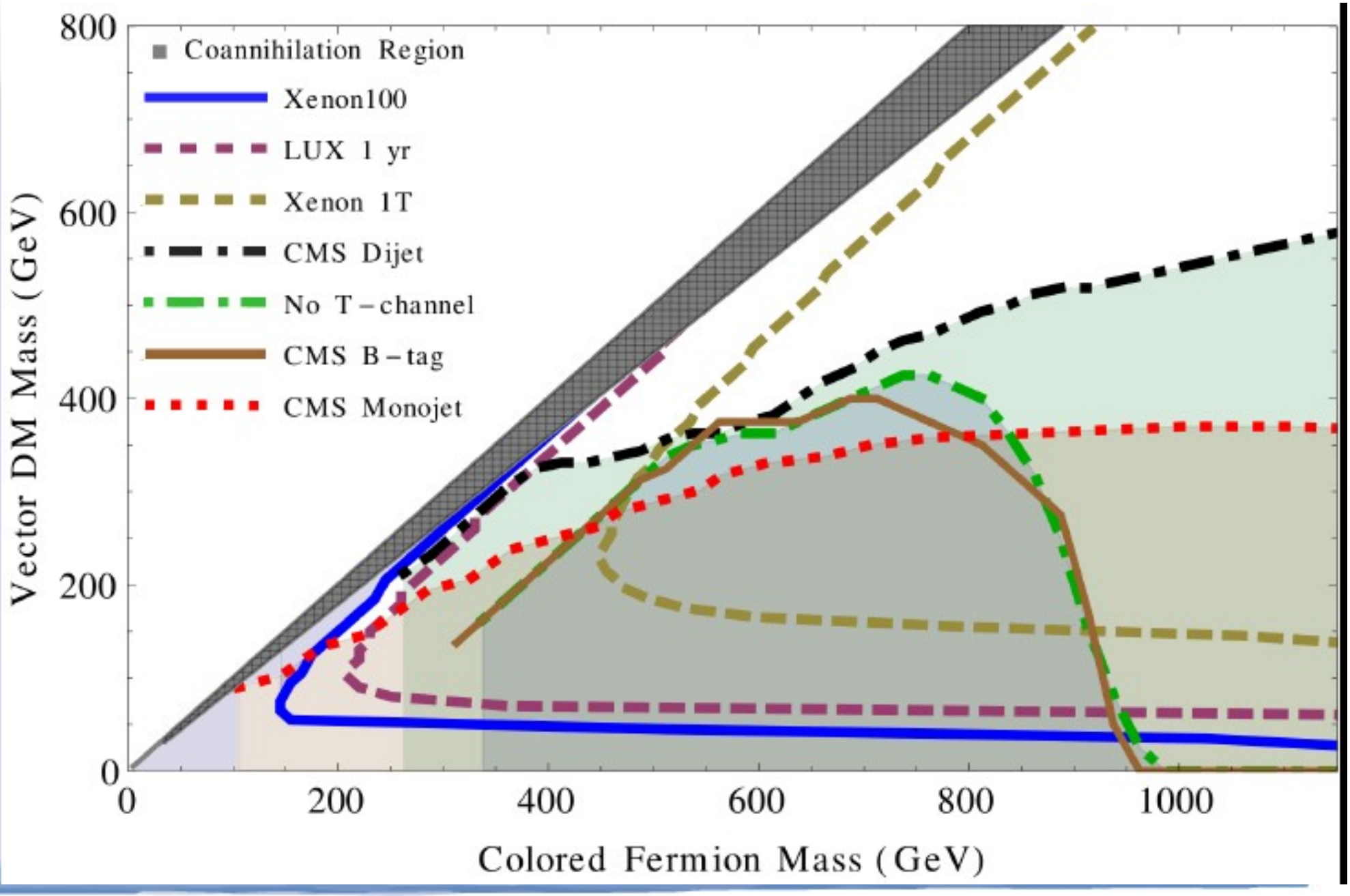
Majorana Dark Matter (3rd Gen.)



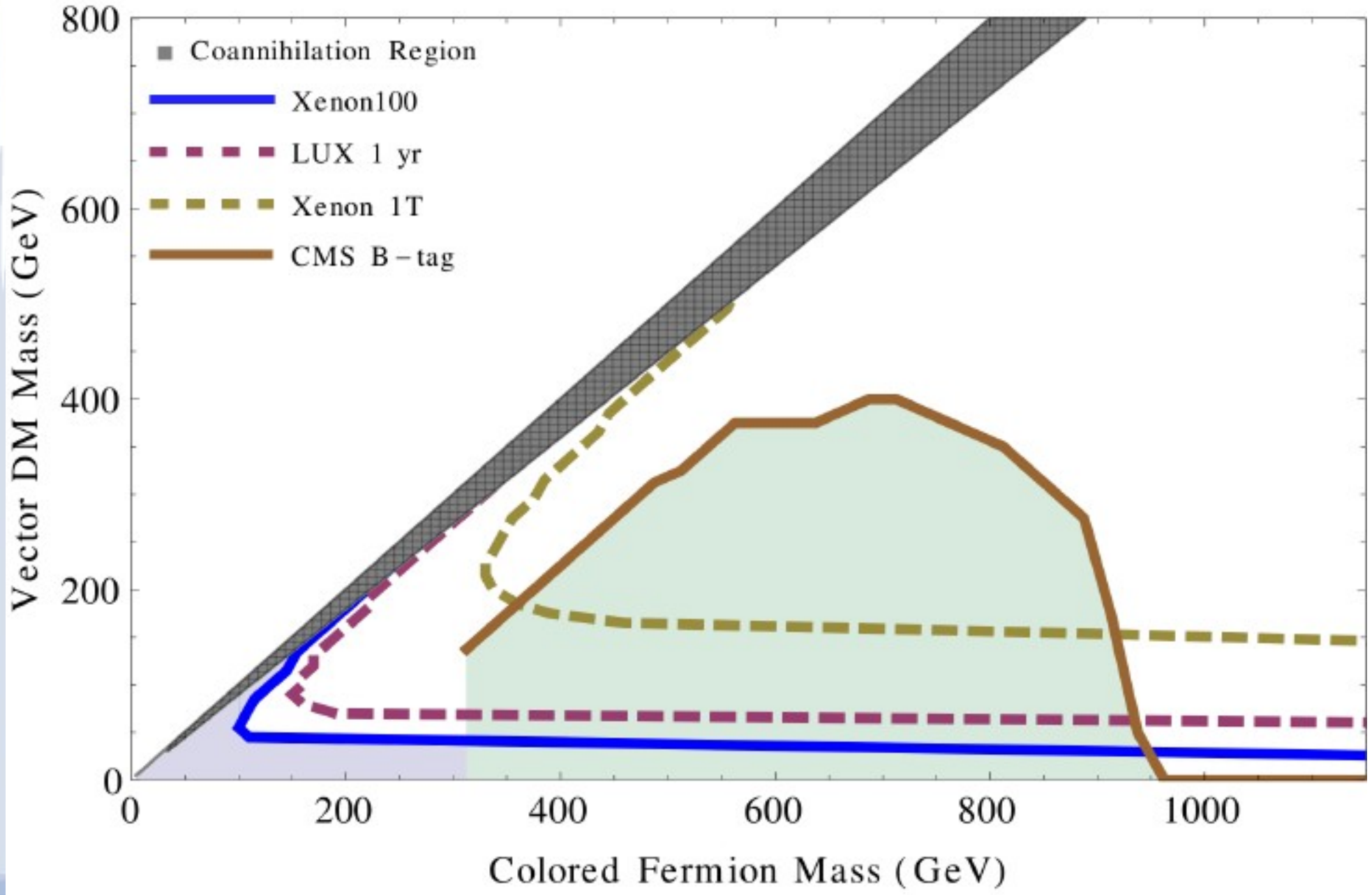
Real Vector Dark Matter (All Gen.)



Real Vector Dark Matter (2 Gen.)



Real Vector Dark Matter (3rd Gen.)



Summary

Simplified Models provide straightforward comparisons of collider and direct detection

Collider & Direct Detection are complementary

Dark Matter must be it's own antiparticle to avoid direct detection

Jets + MET are more sensitive than Monojet searches to simple models of dark matter