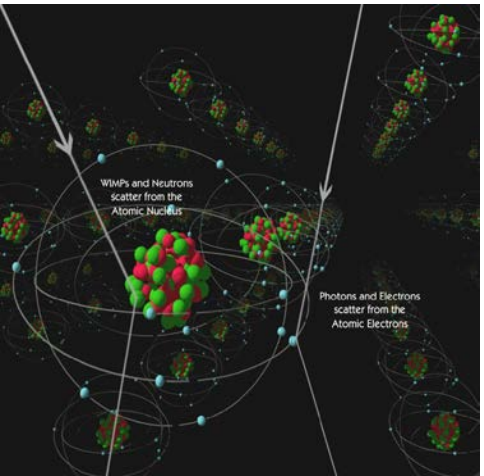
Dark Matter Implications of the DAMA/LIBRA-phase 2 Results

PATRAS Workshop 2018
Juen 21, 2018



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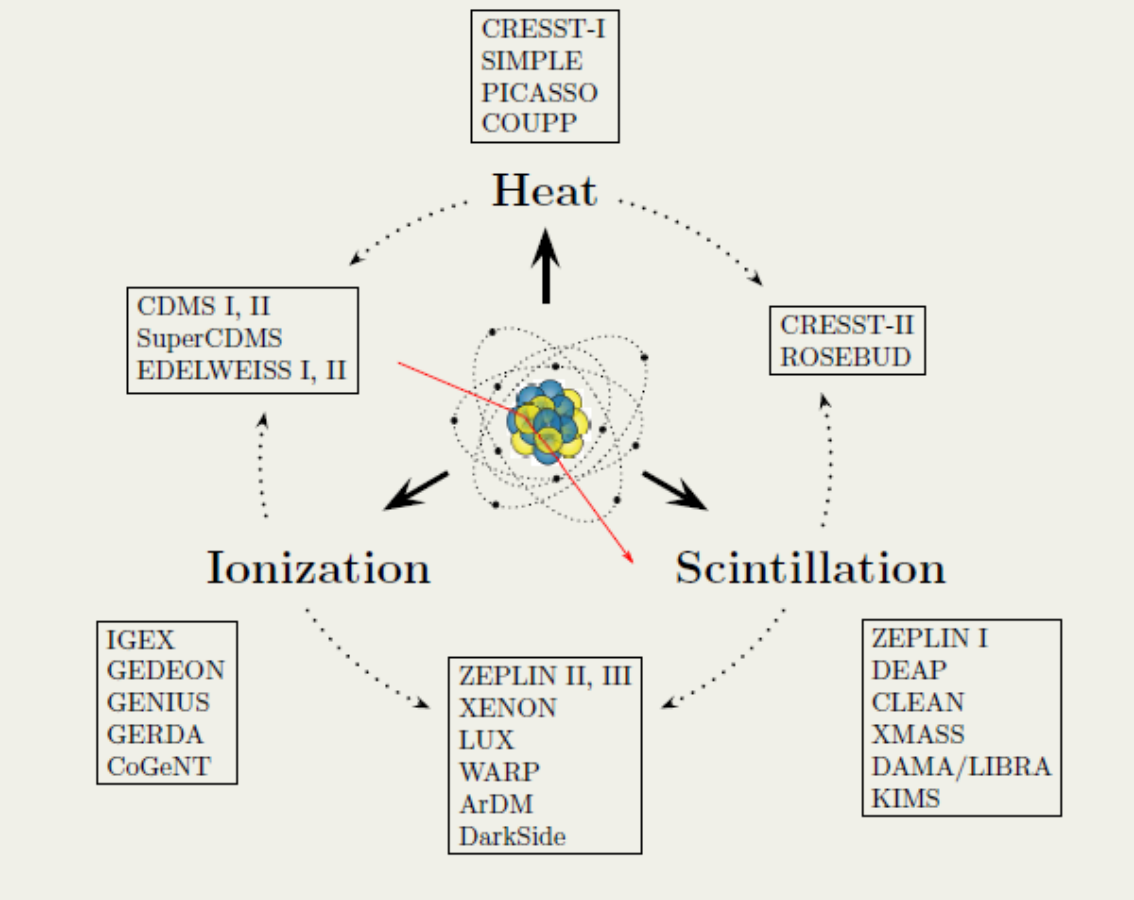
Direct Detection Experiments



Direct Detection Experiments

$$\frac{dR}{dE_R} = N_T \frac{\rho_{DM}}{m_{DM}} \int_{|\vec{v}|>v_{\min}} d^3v \, v f(\vec{v}, \vec{v_e}) \frac{d\sigma}{dE_R}$$

$$v_{\min} = \sqrt{E_R m_N / 2\mu^2}.$$ Defined by kinematics

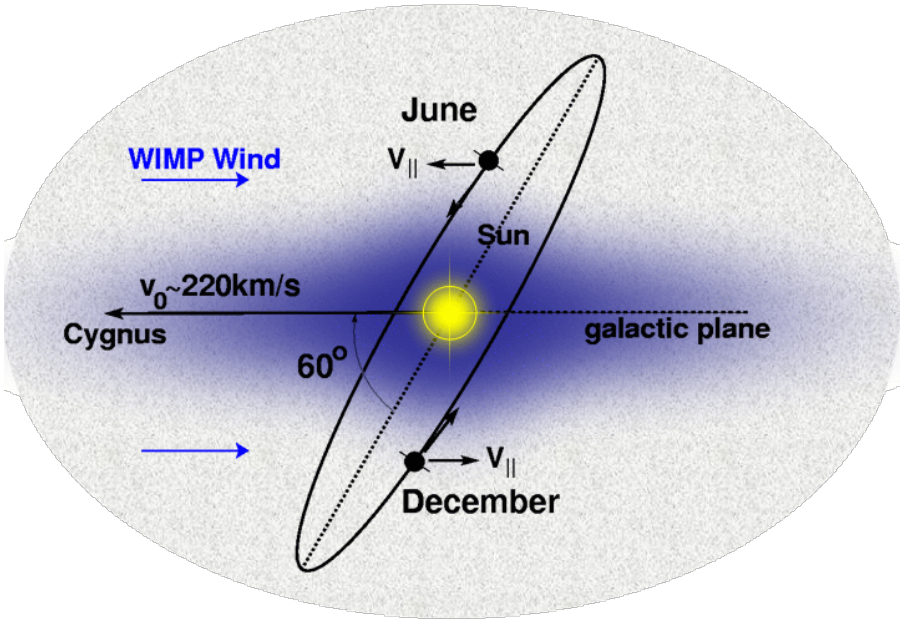
$$\frac{d\sigma}{dE_R} = \frac{m_N}{2v^2} \frac{\sigma_n}{\mu_n^2} \frac{[f_p Z + f_n (A-Z)]^2}{f_n^2} F^2(q)$$

Spin-Independent
Elastic Scattering

Signal in a detector needs inputs from
astrophysics, particle physics, and nuclear physics

Dark Matter Should Have Annual Modulation

$$\frac{dR}{dE_R} = N_T \frac{\rho_{DM}}{m_{DM}} \int_{|\vec{v}|>v_{\min}} d^3v \, v f(\vec{v}, \vec{v_e}) \frac{d\sigma}{dE_R}$$



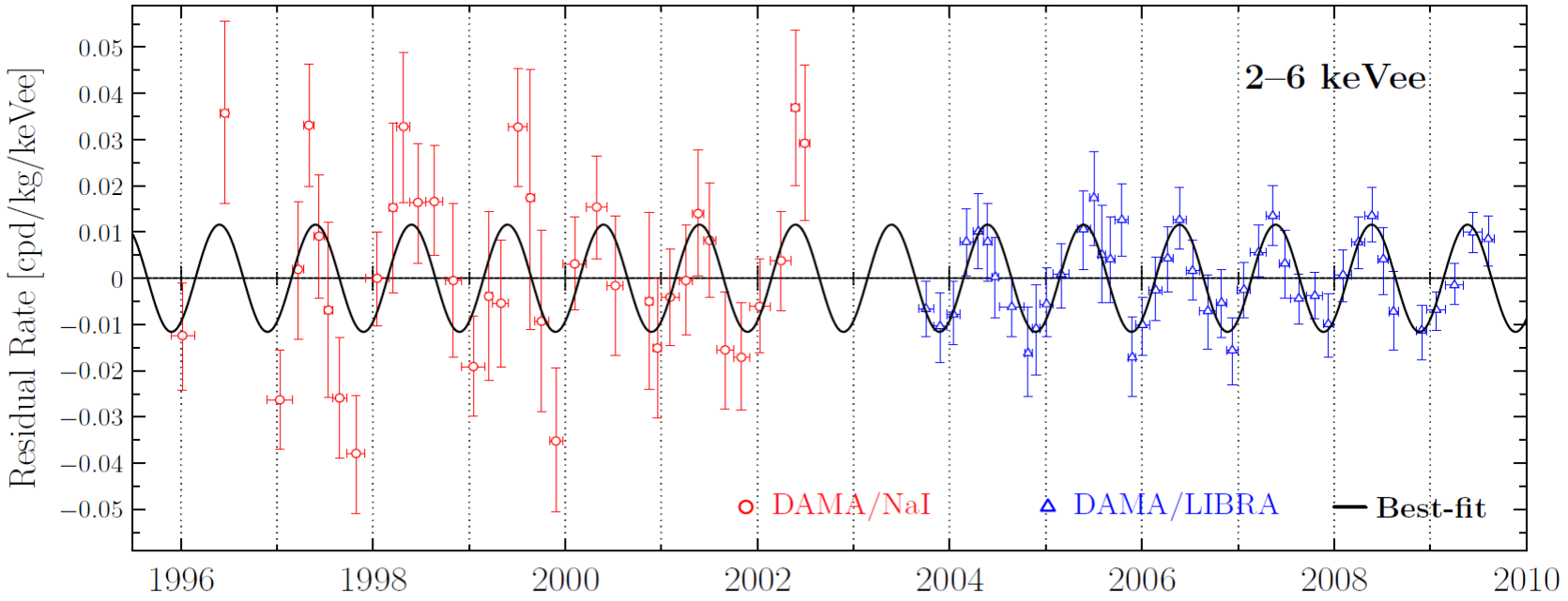
http://www.hep.shef.ac.uk/research/dm/intro.php

DAMA and DAMA/LIBRA (NaI)

- Located in Gran Sasso National Laboratory (Italy)
- Detects only scintillation signal
  - Backgrounds are fairly large
  - Only sensitive to the annual modulation of a dark matter signal
- DAMA used ~100 kg of NaI
  - Collected data over 7 annual cycles
  - Exposure of 0.29 ton-year
- DAMA/LIBRA upgraded to ~250 kg
  - Released data for 7 annual cycles (2010)
  - Exposure of 1.04 ton-year
- DAMA-LIBRA-phase 2
  - Upgraded PMT's (lowered energy threshold)
  - 6 years of data for 1.13 ton-year

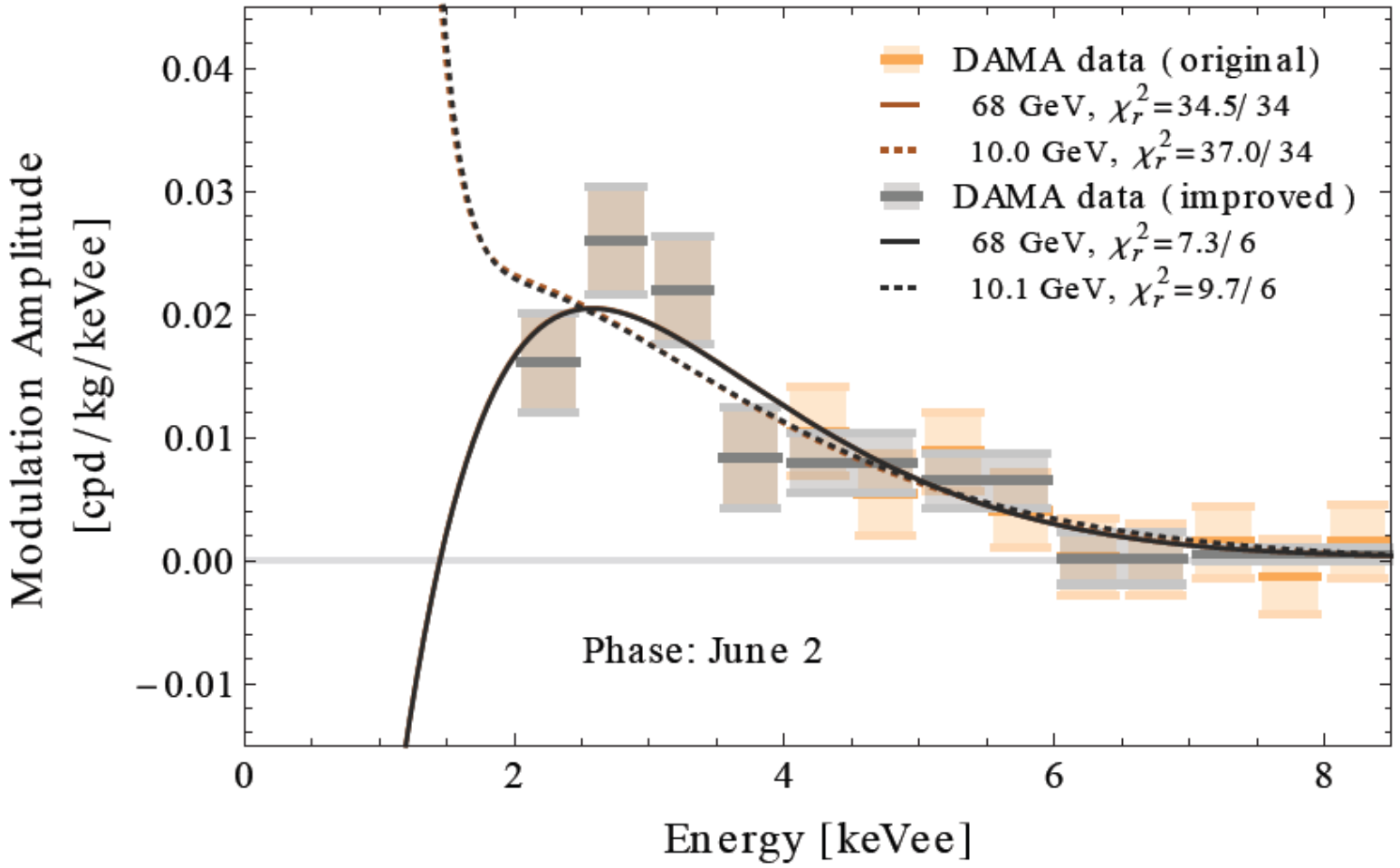
DAMA Results

- Modulation search using NaI crystals (scintillation only)
  - DAMA/NaI: 1996-2002 R. Bernabei *et al.*, Riv. Nuovo Cim. **26N1**, 1 (2003)
  - DAMA/LIBRA: 2003-2009 R. Bernabei *et al.*, Eur. Phys. J. **C67**, 039 (2010)

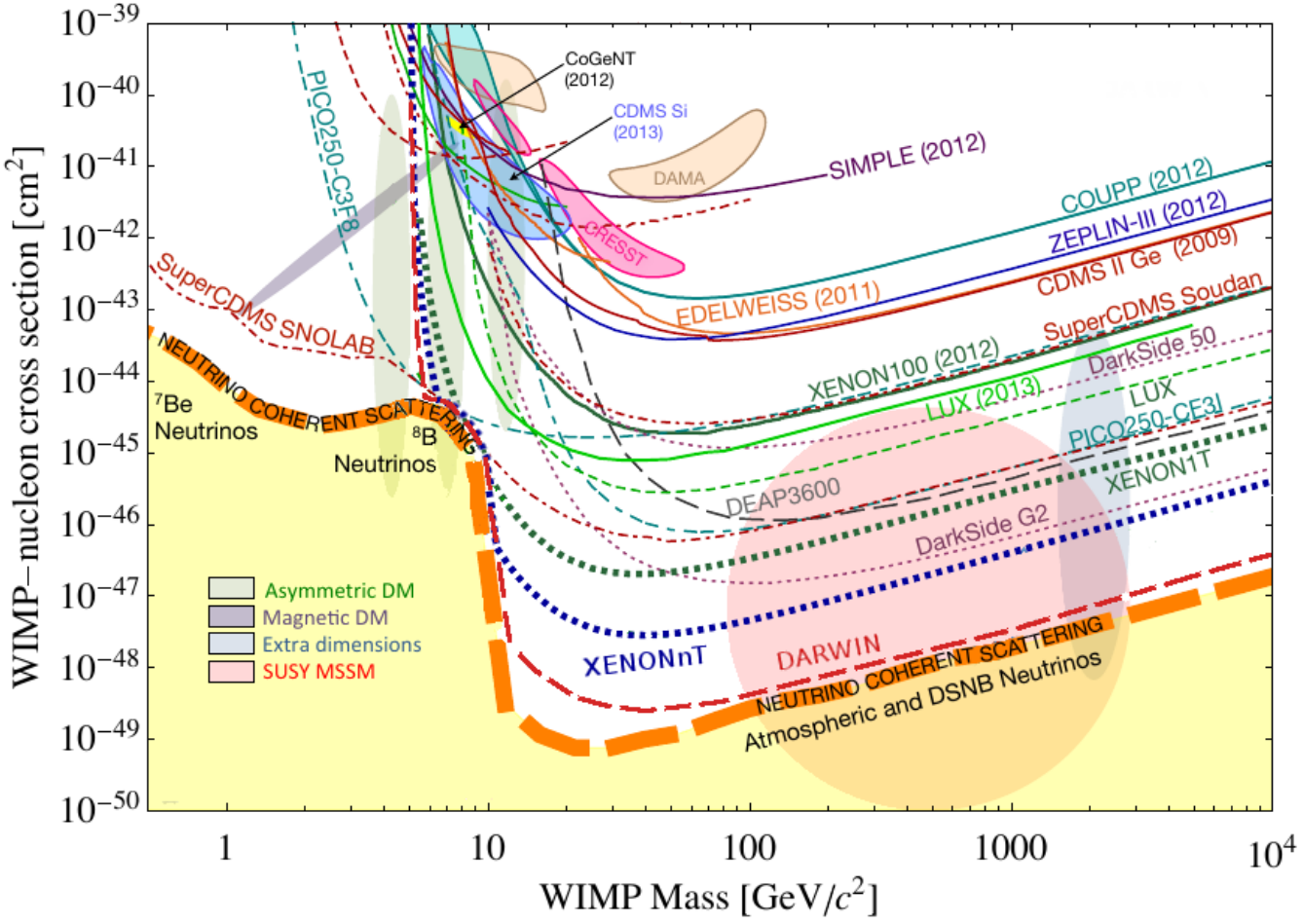


14 years, 1.33 ton years of exposure 9.3σ measurement of annual modulation

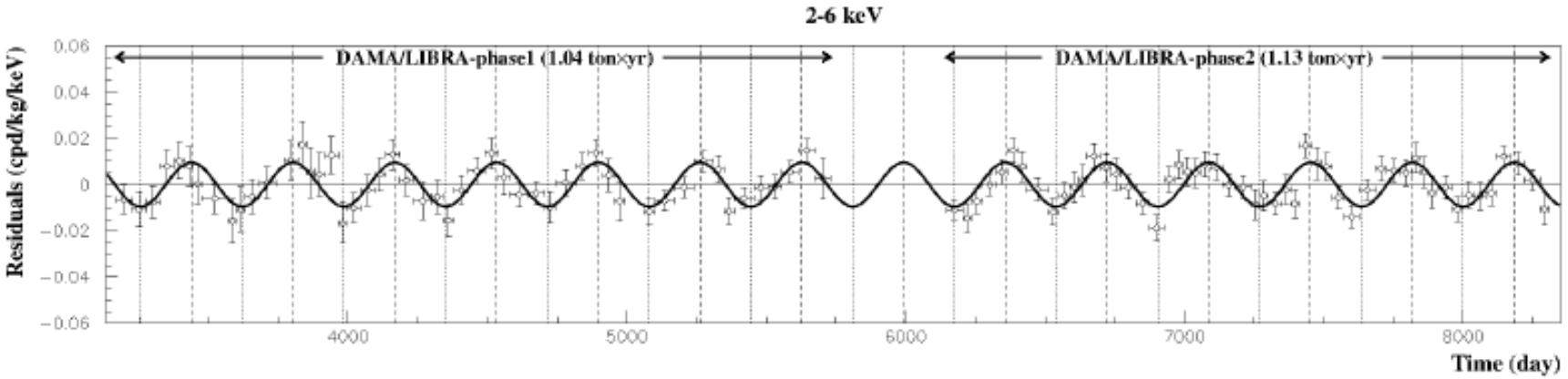
What do we expect in the lower threshold region?



Spin-Independent Scattering

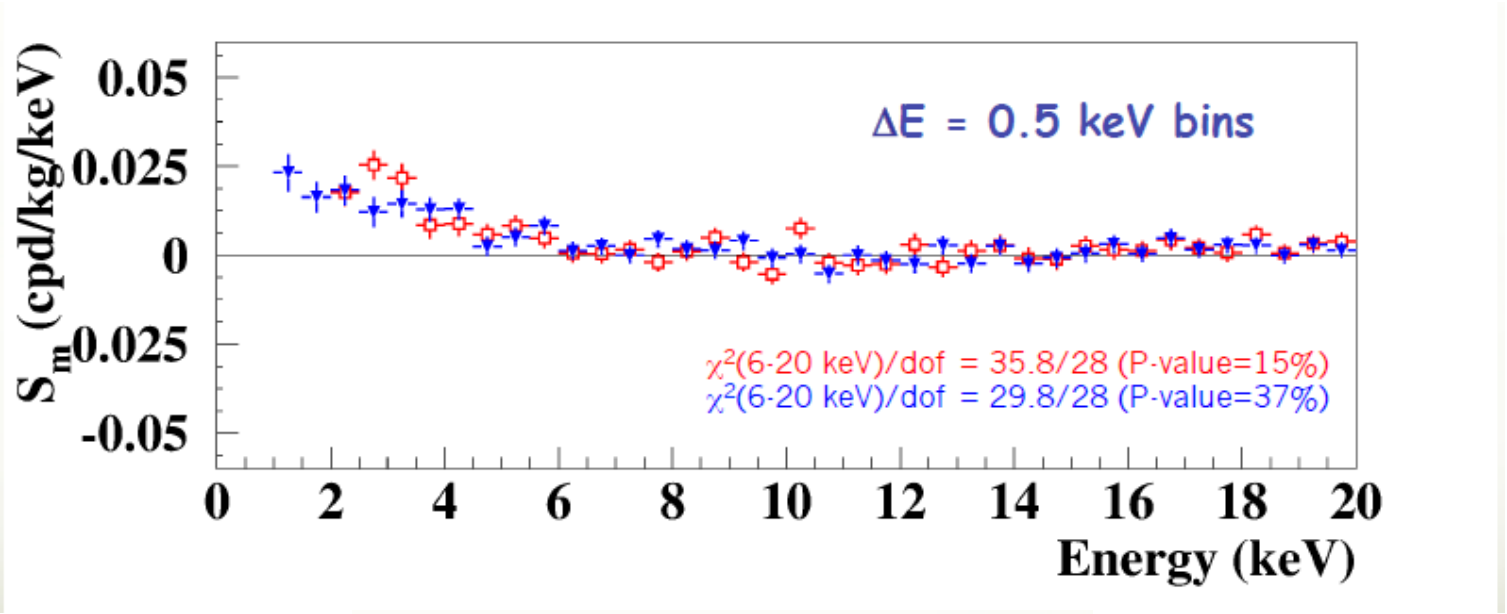


Phase 2: After Upgrade



The data of DAMA/LIBRA-phase1 +DAMA/LIBRA-phase2 favor the presence of a modulated behavior with proper features at 11.9 σ C.L.

New Data

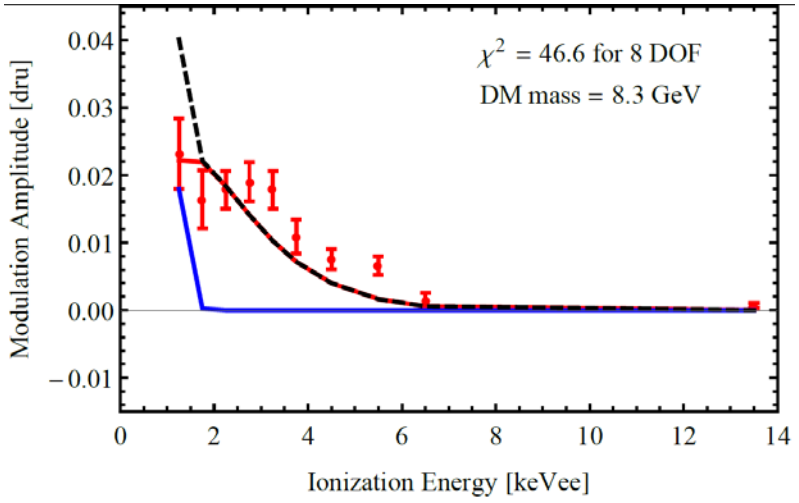


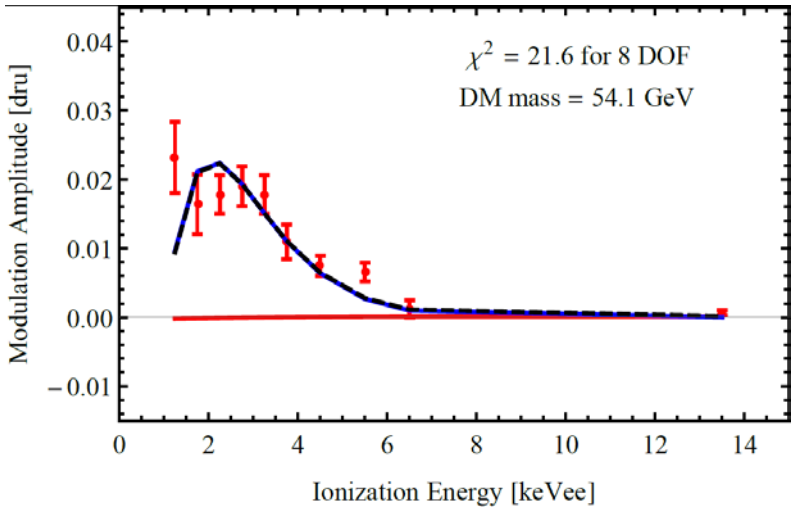
DAMA/NaI + DAMA/LIBRA-phase1

vs

DAMA/LIBRA-phase2

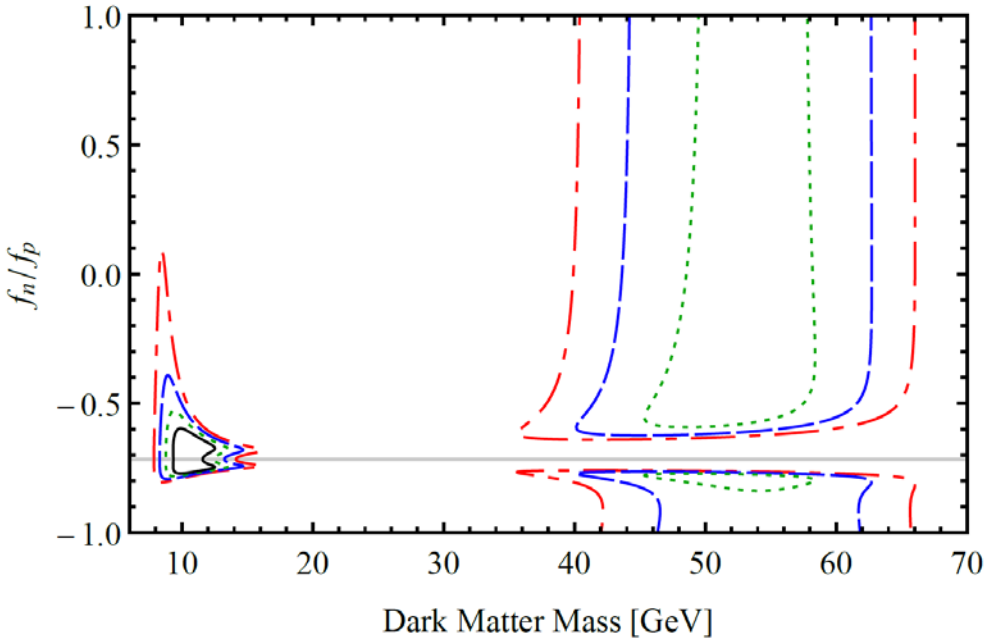
New Best-fit Points – SI Scattering





Red Line: Na Blue Line: Iodine Black Dashed: Sum

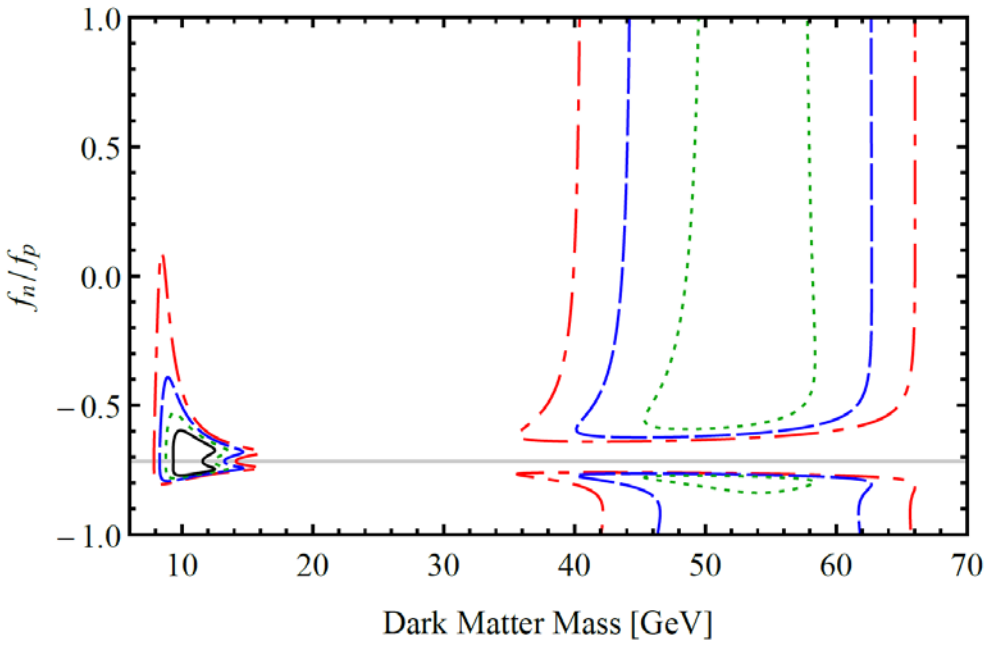
Iso-spin Violating Dark Matter



2,3,4,5σ in Black (solid), Green (dotted), Blue (dashed), Red (dot-dashed)

Iso-spin Violating Dark Matter

Excluded by XENON1T by many orders of magnitude



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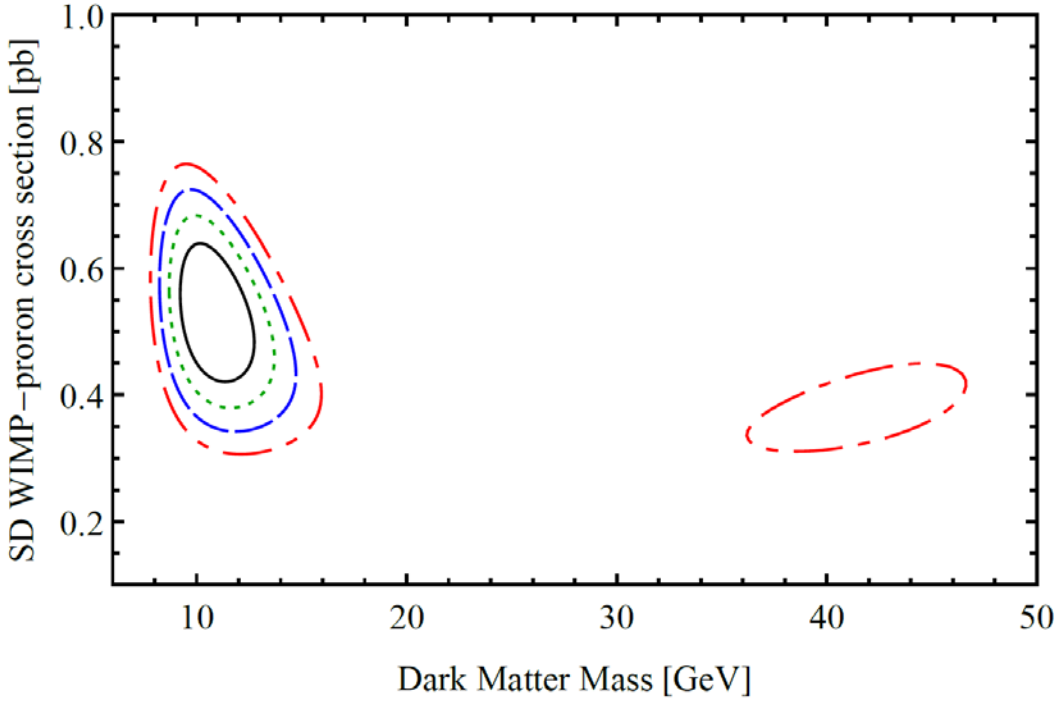
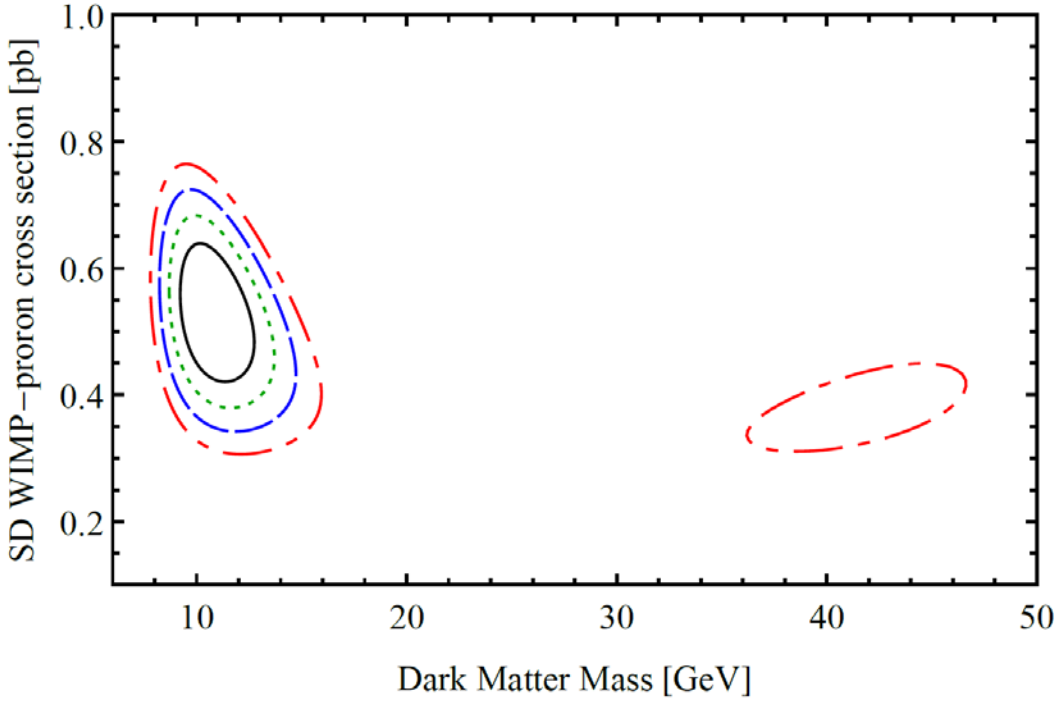
Spin-dependent Proton



2,3,4,5σ in Black (solid), Green (dotted), Blue (dashed), Red (dot-dashed)

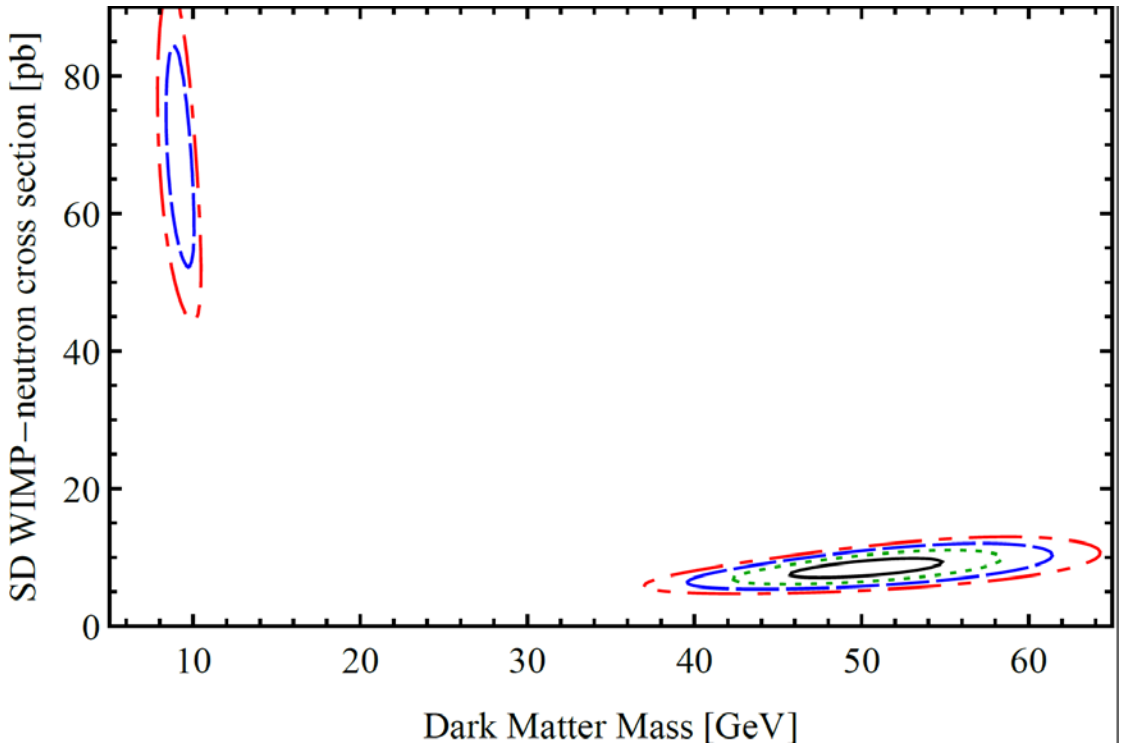
Spin-dependent Proton

Excluded by PICO-60 by many orders of magnitude



2,3,4,5σ in Black (solid), Green (dotted), Blue (dashed), Red (dot-dashed)

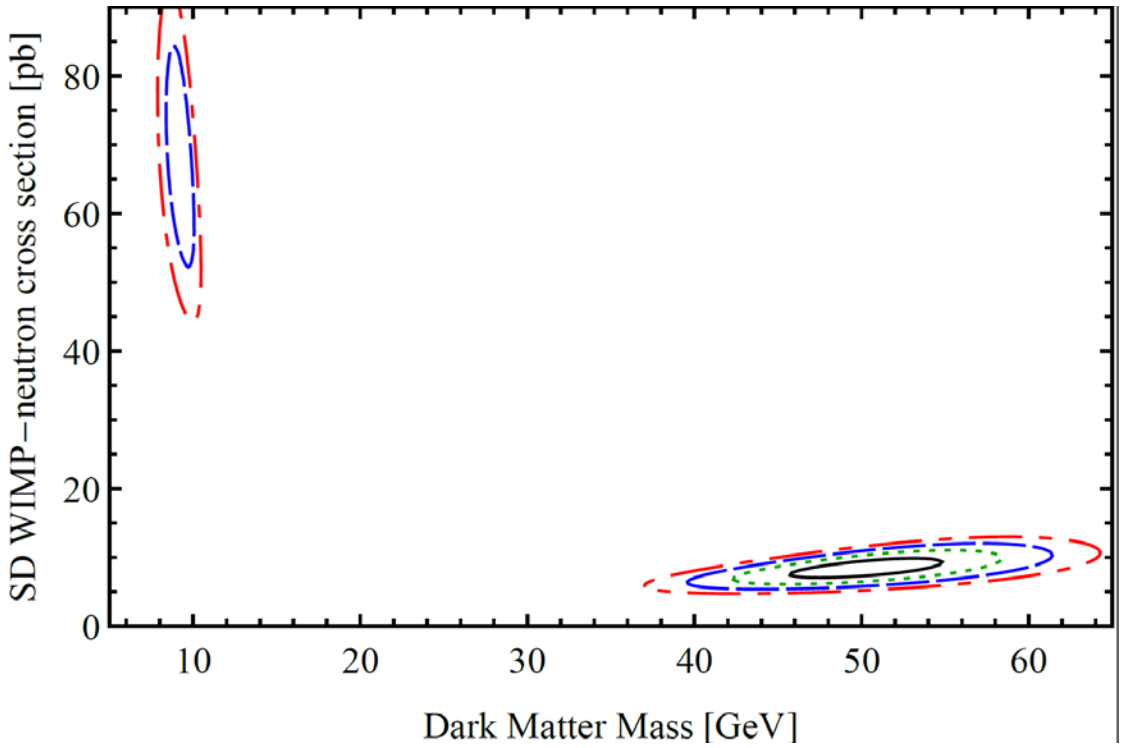
Spin-dependent neutron



2,3,4,5σ in Black (solid), Green (dotted), Blue (dashed), Red (dot-dashed)

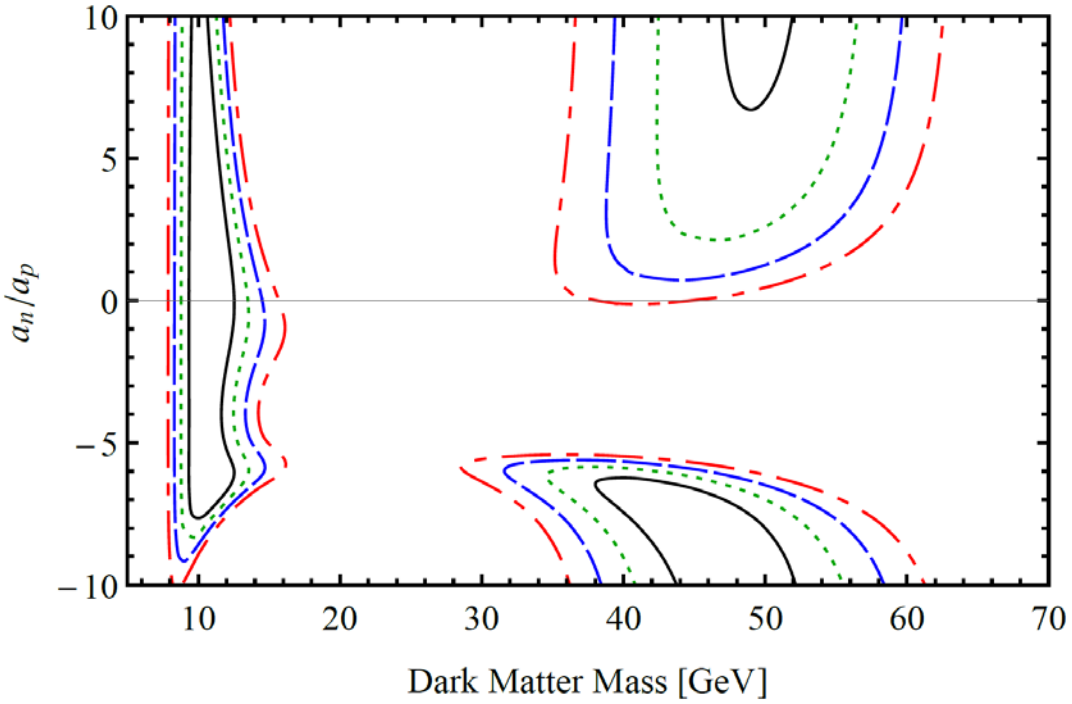
Spin-dependent neutron

Excluded by LUX by many orders of magnitude



2,3,4,5σ in Black (solid), Green (dotted), Blue (dashed), Red (dot-dashed)

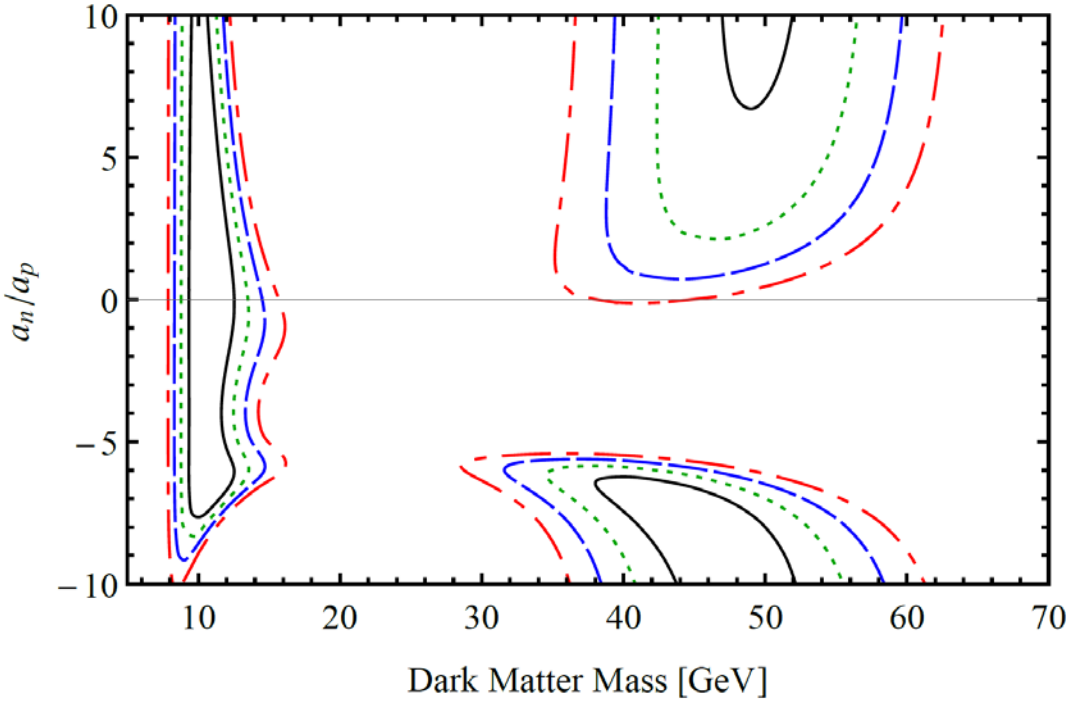
Mixed couplings



2,3,4,5σ in Black (solid), Green (dotted), Blue (dashed), Red (dot-dashed)

Mixed couplings

Likely excluded by many orders of magnitude



2,3,4,5σ in Black (solid), Green (dotted), Blue (dashed), Red (dot-dashed)

Conclusions and Future Outlook

- The upgrade to the DAMA experiment opens up a new energy range and now the simplest model for dark matter no longer fits the data well.
- Many other experiments have excluded this scenario for quite some time, but now DAMA's own data does as well.
- The data can still be fit by looking at spin-dependent dark matter, or more exotic forms such as Iso-spin violating or multi-component dark matter
- These scenarios are all ruled out by many orders of magnitude
- There are currently four different NaI detectors that planned and/or commissioned that will try to reproduce the signal that DAMA is observing.
- Results that will test the DAMA modulation from some of the experiments may be available as soon as 2 years.