Complementarity in Dark Matter Searches

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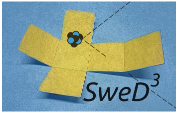
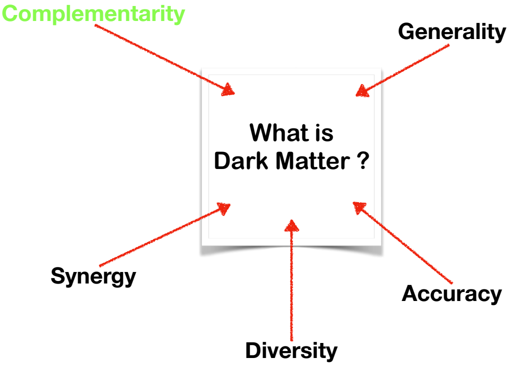




Example: DM Direct Detection

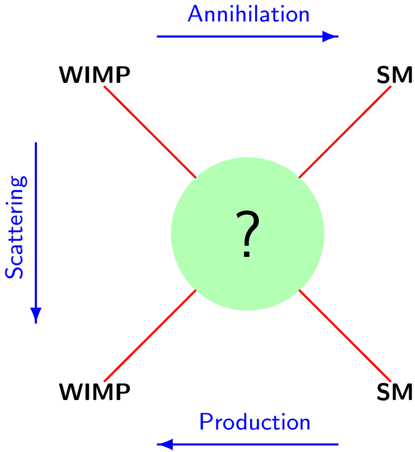
Generality ⇒ Model independent data interpretation via EFT

Accuracy ⇒ Astrophysical and nuclear physics uncertainties

Diversity ⇒ Alternatives to WIMP DM (e.g. Light Dark Matter)

Synergy ⇒ Collaboration with nuclear and solid state physicists

Complementarity⇒ Identifying experimental inputs constraining DM properties unaccessible to direct detection



- The LHC searches for missing transverse momentum in proton collisions
- Direct detection experiments search for DM-nucleus scattering events
- Indirect detection experiments search for DM pair annihilation products

WIMP spin

Hierarchy of constraints

Theoretical framework

- I will focus on a general class of simplified models for spin ≤ 1 DM interacting with quarks
  J. B. Dent, L. M. Krauss, J. L. Newstead and S. Sabharwal, Phys. Rev. D **92**, no. 6, 063515 (2015)
  S. Baum, R. Catena, J. Conrad, K. Freese and M. B. Krauss, Phys. Rev. D **97** (2018) no.8, 083002
  R. Catena, J. Conrad and M. B. Krauss, Phys. Rev. D **97** (2018) no.10, 103002
- Within this framework, models can be classified in terms of WIMP and mediator spin
- Each model is characterised by 4 parameters: two masses and two coupling constants
- Each model can be mapped onto a (linear combination) of DM-nucleon interaction operators
- These operators define the non relativistic effective theory of DM-nucleon interactions (NRET)

Direct Detection – LHC Complementarity

Research question

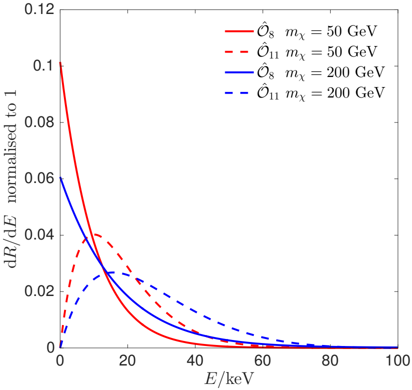
- Direct detection experiments and the LHC are complementary in probing DM models:
  - Direct detection probes coherently enhanced DM-nucleus scattering cross sections
  - The LHC probes models with momentum or velocity suppressed scattering cross sections

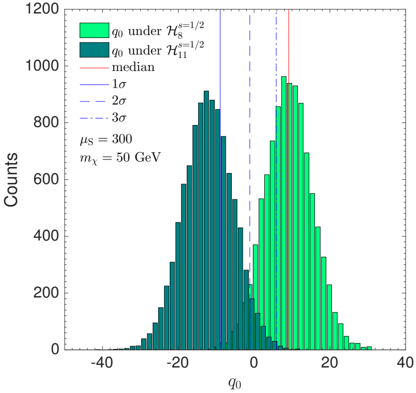
- Can we exploit this type of complementarity to gain insight into the DM particle spin?

- Yes, if an experiment like XENONnT will be able to detection $\mathcal{O}(100)$ signal events

DM particle spin combining direct detection and LHC (I)

S. Baum, R. Catena, J. Conrad, K. Freese and M. B. Krauss, Phys. Rev. D **97** (2018) no.8, 083002
R. Catena, J. Conrad and M. B. Krauss, Phys. Rev. D **97** (2018) no.10, 103002





DM particle spin combining direct detection and LHC (II)

S. Baum, R. Catena, J. Conrad, K. Freese and M. B. Krauss, Phys. Rev. D **97** (2018) no.8, 083002
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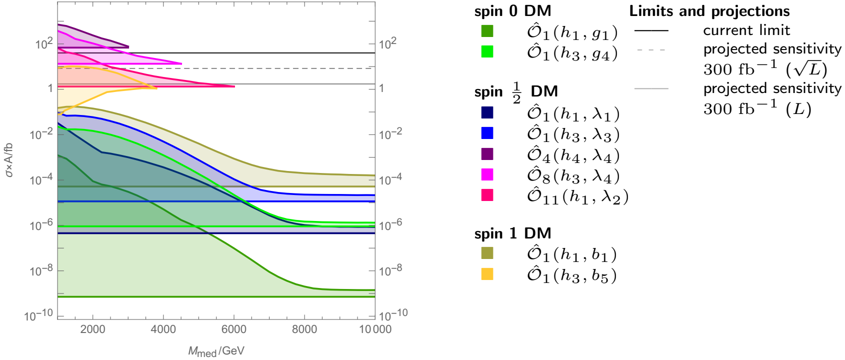


Other approaches to WIMP spin identification

- Large exposure & LHC Run 3 (this talk)

  S. Baum, R. Catena, J. Conrad, K. Freese and M. B. Krauss, Phys. Rev. D **97** (2018) no.8, 083002
  R. Catena, J. Conrad and M. B. Krauss, Phys. Rev. D **97** (2018) no.10, 103002

- Large exposure & directional information

  R. Catena, J. Conrad, C. Dring, A. D. Ferella and M. B. Krauss, Phys. Rev. D **97** (2018) no.2, 023007

- Large exposure & polarised target materials

  R. Catena, K. Fridell and V. Zema, arXiv:1810.01515 [hep-ph].

Direct Detection – Neutrino Telescopes Complementarity

Research question

- Direct detection experiments and neutrino telescopes are complementary in probing DM models:
  - Direct detection probes coherently enhanced DM-nucleus scattering cross sections
  - Neutrino telescopes probe spin-dependent DM-proton scattering cross sections

- Is there any other type of interaction that neutrino telescopes can probe better than direct detection?

- Yes, inelastic DM-nucleus interactions, for large mass splittings between incoming and outgoing DM particle

- When there is a mass splitting δ between incoming and outgoing DM particle, one has

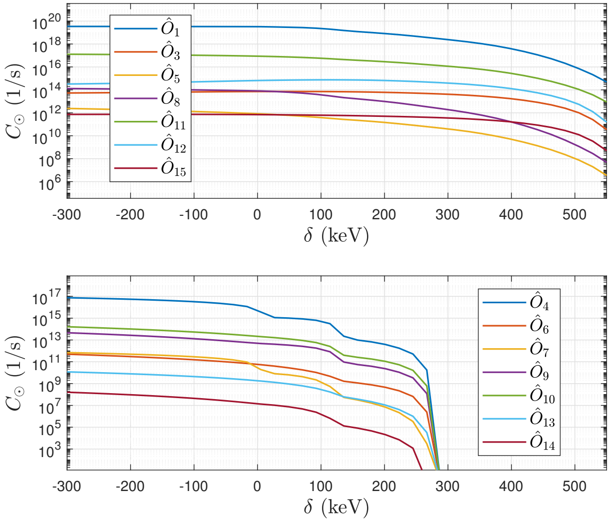
$$E_R^{\pm} = \frac{\mu^2}{m_T} w^2 \left(1 \pm \sqrt{1 - \frac{2\delta}{\mu w^2}} \right) - \frac{\mu}{m_T}\delta$$
$$w \geq w_{\min} \equiv \Re\sqrt{2\delta/\mu}$$

- Furthermore, when the DM particle is heavier than the target nucleus, one finds

$$E_R^- \simeq \delta\,; \qquad w_{\min} \simeq \Re\sqrt{2\delta/m_T}$$

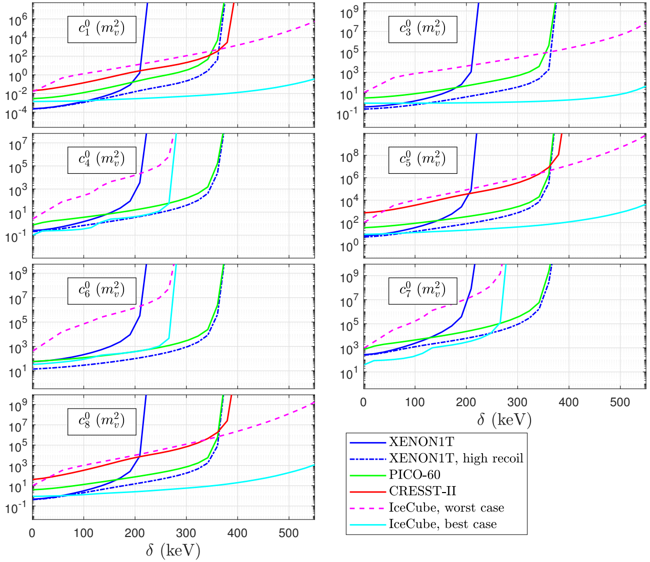
Solar capture rates

R. Catena and F. Hellström, arXiv:1808.08082



Exclusion limits from IceCube and direct detection

R. Catena and F. Hellström, arXiv:1808.08082



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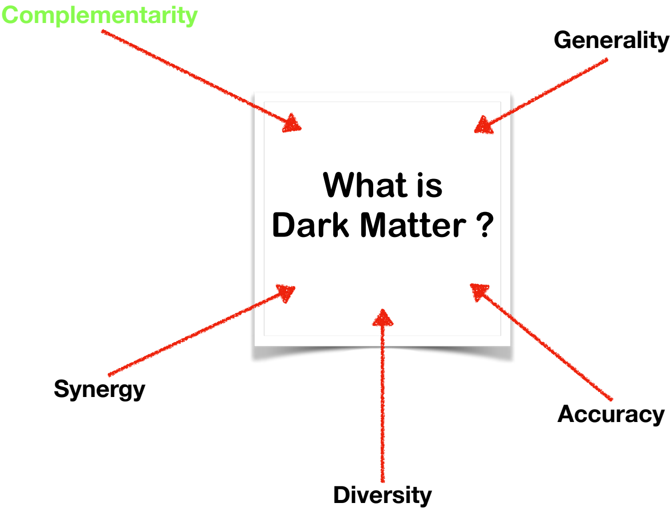
Conclusion


Complementarity
Generality
What is
Dark Matter ?
Synergy
Accuracy
Diversity