Low Mass DM in Liquid Noble Detectors

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290E

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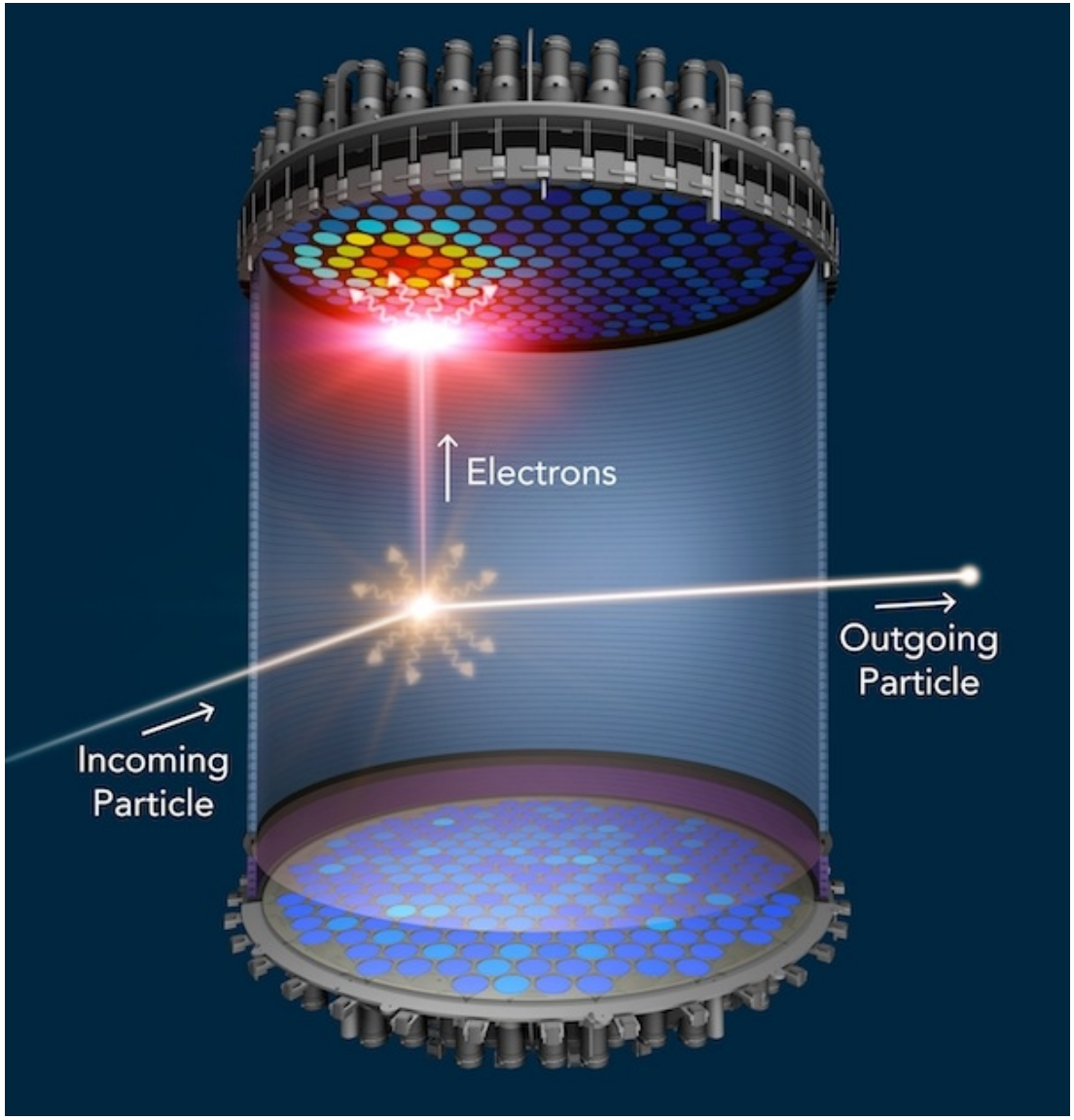
Liquid Noble DM Detectors



Why Liquid Nobles?

Lots of success in the "Heavy" WIMP space

- Scalibility
  - Want a bigger detector? Buy a bigger bucket
  - The bigger the better
- Proven technology
  - "Just" PMTs + electric field
- Multiple observation channels
  - NR/ER discrimination

Why (Not) Liquid Nobles?

Conventional wisdom: Liquid Nobles good at heavy masses, cryogenic calorimeters good at low masses

- Inherent threshold limitations
  - Current Xenon TPCs can't really reduce thresholds by x10 operating in the same way
  - 10-20 photons per KeV $\rightarrow$ 50-100 eV per photon in Xe, Ar not better
  - Already single charge sensitive
- Xe, and Ar heavy nuclei
  - Less momentum transfer from "light" DM

Why Liquid Nobles? (for real this time)

New strategy:

- Retain most or all of benefits from traditional liquid noble TPCs
  - Scalibility, low backgrounds, proven design, etc.
- Lighter targets
  - He, e^-, etc.
- Lower thresholds
  - Higher yield targets
  - New ideas

Idea 1: LZ (or XENONnT ...) with He

Benefits:

- Huge mass!
- Light target, more efficient energy transfer!
- We know how to do this, just take out Xe and add He

Drawbacks:

- Higher ionization energy, less yield, harder to ionize atoms
- Leaving a lot of energy on the table, most energy goes into undetected heat/quasiparticles

Idea 1.1: LZ with He, looking at heat

Idea:

- Pick up heat signal, in addition to light signal

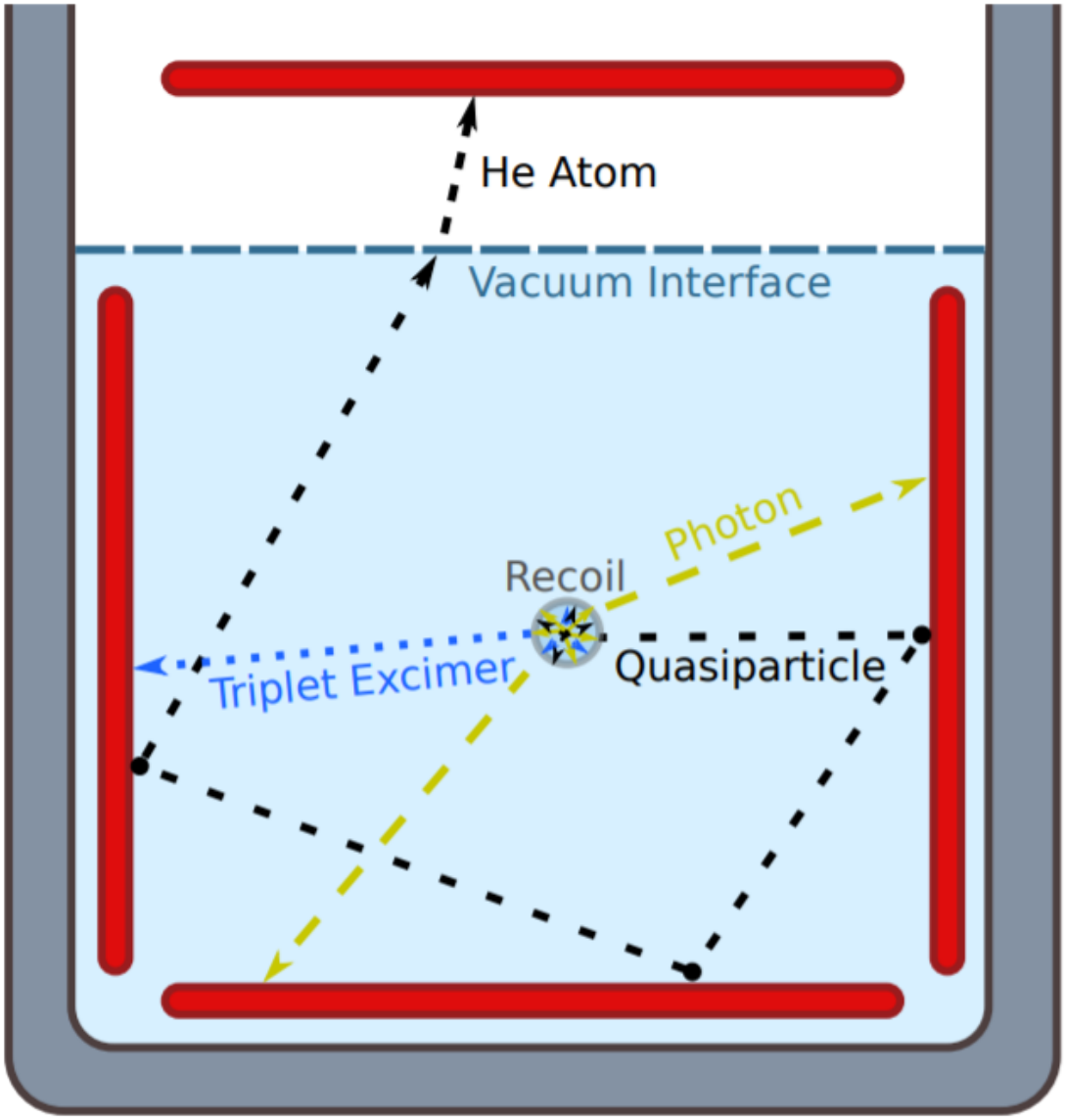
Benefits:

- Essentially limitless* energy threshold
  - With an arbitrarily sensitive calorimeter, you can see signals as low as 1 meV
  - Can also ionize quantum evaporated He atoms

Drawbacks:

- Need to do at mK temperatures if you want low thresholds
  - Superfluid creep...
- Calorimetry arrays are harder than PMTs
- Overall, lots of technical challenges

Ideal 1.1: HeRALD



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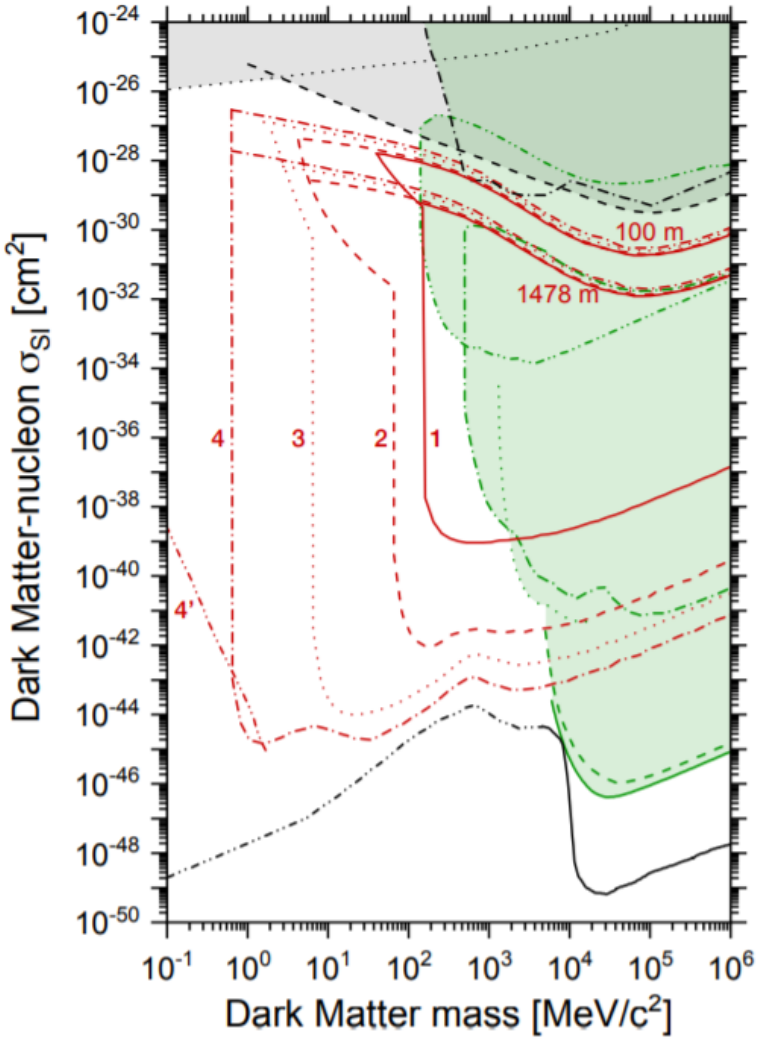

From arXiv 1810.06283

Idea 1.2: LZ with just a little bit of He

Idea:

- Mix a little (about 0.1 percent) of He into the Xe of an LZ-like lXe TPC
  - Also works with Ne, H

Benefits:

- Really, really easy*, just mix He into existing experiment
  - OK, would need different getters, questions about PMT performance, but there's no reason it couldn't be an LZ upgrade
- Low mass He nuclei good for recoils, proven Xe performance

Drawbacks:

- Lose some mass compared to pure He concept
  - Not a big deal, you don't need a lot of mass to do good low mass work
- Still limited in inherent threshold by Light + Charge yields
- Uncertainty about how recoil will behave compared to Xe NR/ER

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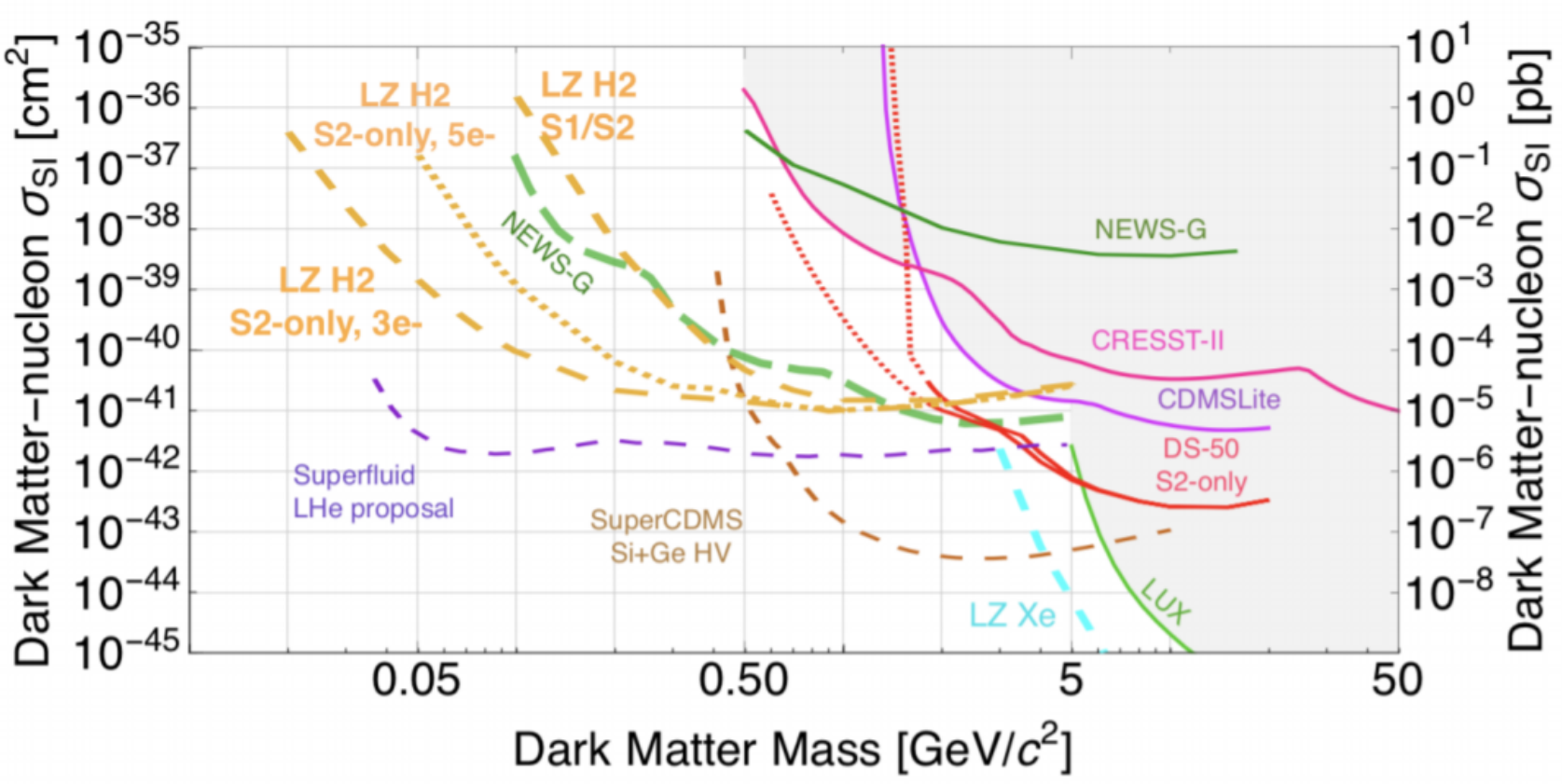

From "HydroX" talk, Alissa Monte, Aug 1 2019

Idea 2: LZ

Idea:

- Electrons are really light, certainly could interact with DM
- LZ is already really good at looking for electron events
  - So called "S2 only" searches

Benefits:

- There's really no experiment to build, it's just a different analysis
- LZ has a lot of electrons, and is already single electron sensitive

Drawbacks:

- LZ is already single electron sensitive
  - No opportunity for improvement...

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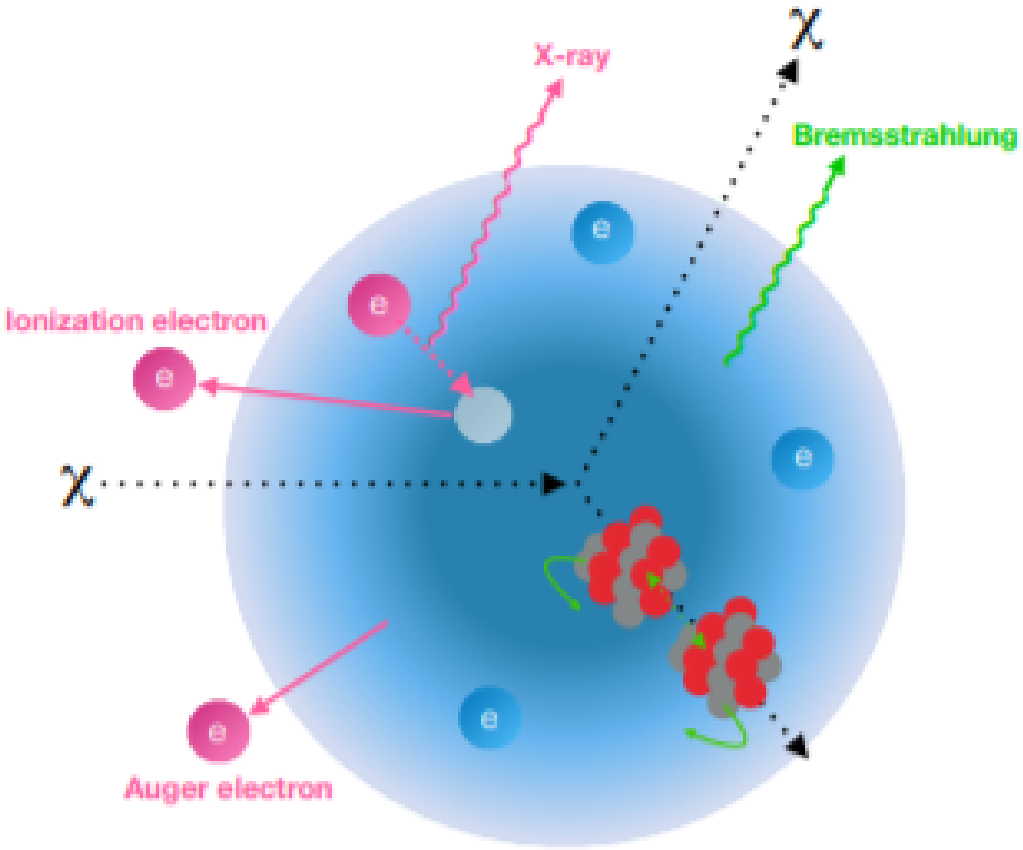

XENON1T paper: arXiv 1907.12771

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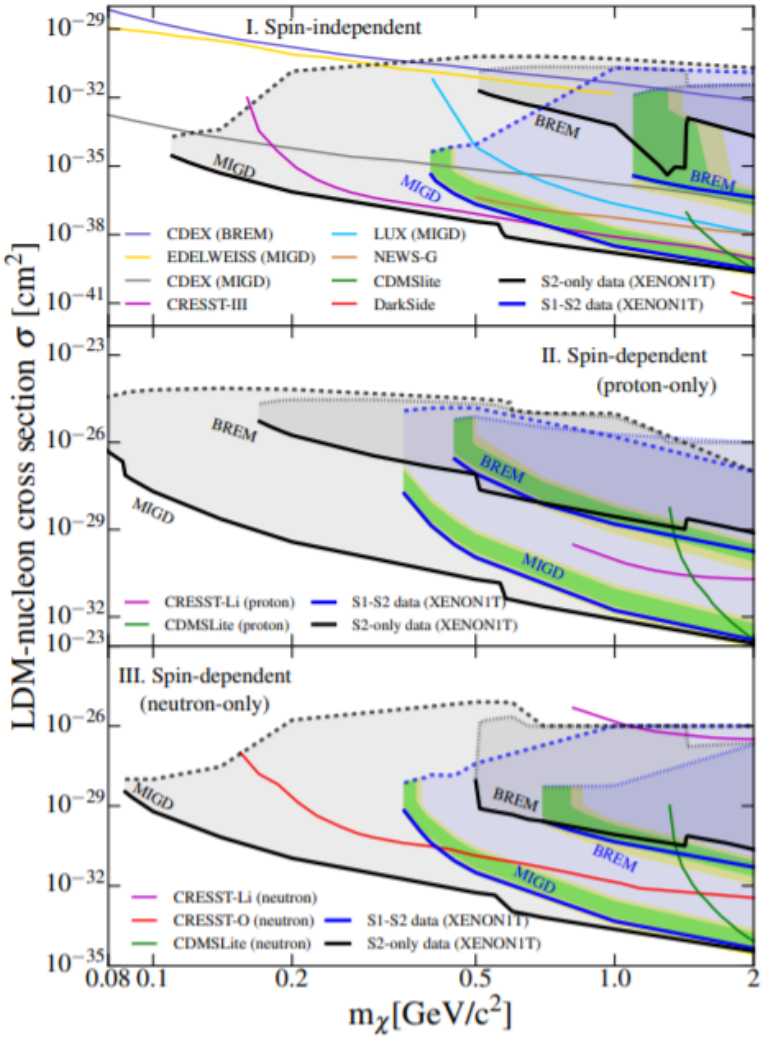

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Summary

Two main ideas:

- Look at NRs off of lighter liquid nobles
- Look at electron events in existing Xe TPCs

Old paradigm:

- Liquid noble TPCs great for high mass WIMPs, solid state detectors great for low mass WIMPs

New landscape:

- Liquid nobles great for high mass WIMPs, lots of promise, new ideas for low mass WIMPs