Summary of Dark Matter Inputs to the Roadmap

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Light Dark Matter at Boulby
Liquid Argon
Liquid Xenon
MAGIS

Dark Matter Summary Comments

- Dark Matter and other new physics are strong physics motivations (STFC C:4)
- A quickly **growing subfield** both in membership in individual projects, and new projects
- Input submissions highlight opportunities for leadership if funding is expanded in this area
  - Difficult to judge purely by numbers of researchers, as existing funding also shapes the field
  - UKRI Quantum Technology for Fundamental Physics interest and results (recent HEP Forum discussions) highlight this breadth
- **Boulby Underground Laboratory is a key facility**
- Summarising 4 inputs now, encourage more!

Light DM at Boulby: EFCu and DarkSPHERE

- Rare-event search experiments rely upon electroformed copper for their physics goals (dark matter and neutrinoless double-beta decay)
  - ECUME at SNOLAB, partnered with PNNL, bring experience to Boulby
- Low-mass dark matter searches with NEWS-G
  - Dark Matter search in 0.05 -10 GeV mass range, aiming for the neutrino ‘floor’
    - motivated by hidden sectors, asymmetric dark matter, and effective field theory
  - Cu Spherical Proportional Counter filled with light gas mixtures
    - SEDINE at LSM 60 cm dia., SNOGLOBE at SNOLAB 1.4 m dia, DarkSPHERE at Boulby 3m dia.
      - swappable targets, single ionization electron sensitivity, background rejection and fiducialisation

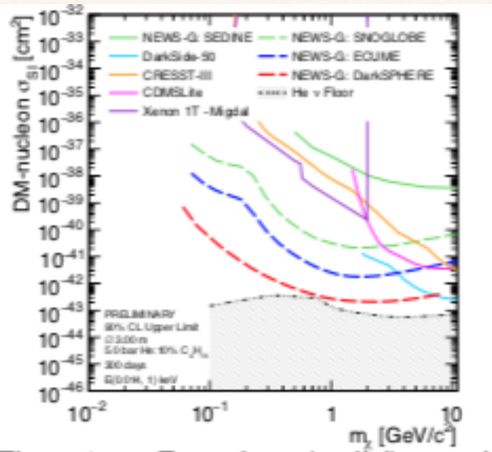
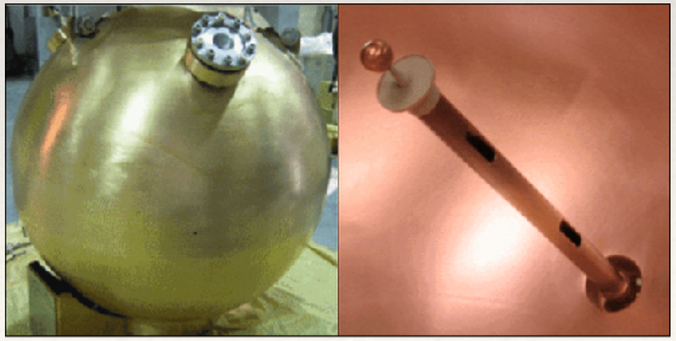


Fig. 1: Results (solid) and projections (dashed lines) for DM sensitivity; and He neutrino floor.



Light DM at Boulby: UK spotlight

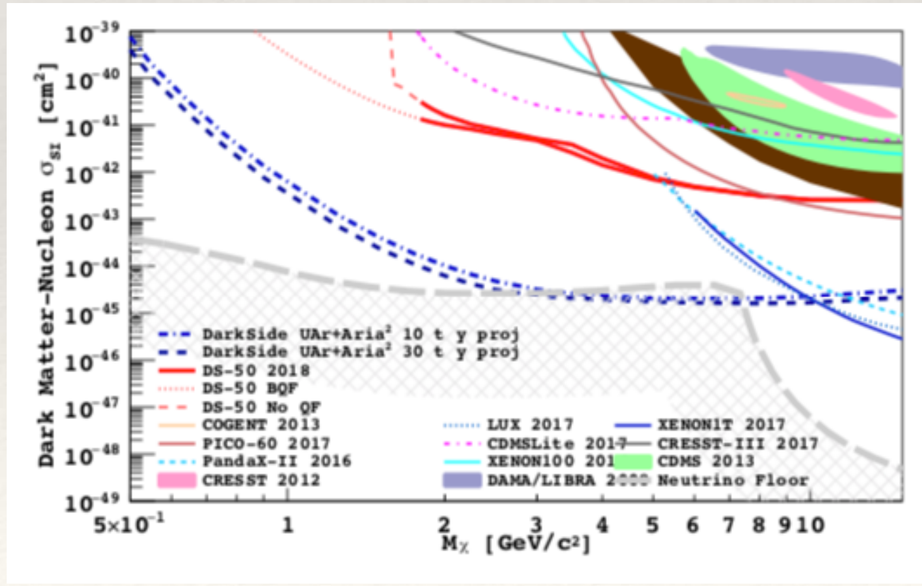
- UK groups: **Boulby, KCL, RAL, RHUL, UCL, Birmingham, Liverpool**
- Build EFCu expertise at SNOLAB and establish underground electroforming at Boulby
  - builds on Boulby's world-leading ultra-low background assay facility
  - R&D on electroformation mandrel and electrolyte
  - cost optimization and links to industry
- SoI for NEWS-G DarkSPHERE at Boulby

Liquid Argon Dark Matter Direct Detection

- Dark matter detection is a high priority: STFC C:4
- Liquid argon targets are attractive across a wide dark matter mass range
  - multiple targets are complementary in EFT models
  - argon provides strong background rejection of electronic recoils
  - argon detectors can scale to large target masses
- Global Argon Dark Matter Collaboration (GADMC) joined together 4 previous collaborations
  - Program of multiple detectors sequenced in scale, starting with DarkSide
    - 50 tonne detector at LNGS, funded by INFN, NSF and CFI, to run from 2023
    - future: DarkSide-LM (timescale 2026-2030)
  - SiPM based photosensor technology of bonded SiPM tiles integrated with cryogenic front end electronics: the photon detector module (PDM)

DarkSide-UK Spotlight

- UK groups: **RHUL, Glasgow, IPPP, KCL, RAL, Open University, Sheffield, Liverpool, Warwick, Birmingham, Lancaster, Manchester, Imperial**
- Leadership in DarkSide and predecessor DEAP-3600
  - DEAP: Institutional Board Chair; Calibration Commissioning Coordinator; Software Coordinator; and DM Search Analysis Working Group Convener
  - DarkSide: 8 L1-L3 technical leads in photoelectronics, outer detector, and simulations
- Propose SiPM development and production
  - Reduce radioactivity in front end electronics
  - 3D integrated sensor at lower radioactivity and production costs
  - Awaiting PPRP funding decision, matched with external collaboration funds in excess of UK request
- DarkSide-LM at Boulby
  - Utilize WATCHMAN-AIT platform after WATCHMAN run ends



DarkSide-UK Partnerships

- UK HEP
  - Si expertise from LHC, SiPMs & cryogenic ASICs of interest to wider DM & neutrino fields, as well as astronomy and non-proliferation studies
  - LAr technology overlap with DUNE, LEGEND,
  - Direct detection and collider complementarity in DM search
- UK Industry
  - Harwin and e2v for sensor production
- Global Science
  - Partnerships with Canada, Italy, Mexico, and other Latin American countries
- Global Industry/National Labs
  - FBK and TRIUMF for Si sensors
- Public Engagement
  - Pb contamination in water
  - PET scans
  - LIDAR
  - Education and public interest in DM

Liquid Xenon Rare Event Observatory

- LXe targets have a long history of world-leading limits in direct detection experiments
  - LZ and XENON-nT are transitioning to operations
  - expect at least one global LXe 50-100 tonne detector, expectation of collaboration growth
- Science opportunities for a LXe target
  - Dark matter over 5 decades of mass, reaching the neutrino ‘floor’
    - spin-dependent sensitivity and sensitivity to most EFT operators, complementary to the LHC
      - isotopic composition may be altered for signal studies
    - doping with light elements to extend the reach
  - Astrophysical neutrinos can be seen via CEvNS (solar 8B and supernova)
  - Electronic recoil signals
    - XENON1T excess and similar possible from solar neutrinos, ALPs, exotic DM models
    - double electron capture and neutrino-less double beta decay of Xe isotopes

Liquid Xenon UK Spotlight

- UK groups: **Imperial, Oxford, Liverpool, UCL, Bristol, RAL, RHUL, Sheffield, KCL, Edinburgh**
- UK leadership in LXe program from ZEPLIN-I/-II/-III, LUX, LZ
  - many leadership roles on those experiments
  - active in pushing the sensitivity of the technology
  - pursuing Boulby feasibility studies
- Preparatory R&D is commencing for next generation detectors
  - including demonstration of the Migdal effect

MAGIS-100 and AION

- Atom interferometer for physics beyond the standard model
  - dark matter and dark forces
  - test quantum mechanics
  - working towards larger detector (1 km baseline) for gravitational waves
    - aimed midband from 0.1Hz-10 Hz between Advanced LIGO and LISA
- Relies upon atomic clock technology
- MAGIS-100 100m long at Fermilab
  - First physics before 2024
- AION in future in UK, for distributed network of interferometers

MAGIS-100 and UK spotlight

- UK groups: **Liverpool, Cambridge, Oxford**
- UK funding through UKRI QFTP program
  - MAGIS in US through DOE HEP and Moore Foundation
- UK responsible for interferometer detection system
  - optics, camera system and enclosures
  - DAQ and computing pipeline
  - time synchronisation between MAGIS and AION