

DarkSide-LowMass: feasibility for low mass dark matter discovery at Boulby



Darren Price

on behalf of the DarkSide-UK community Boulby Underground Laboratory Development Feasibility Meeting February 26th 2021

DarkSide a staged programme to discover dark matter (DM) particles scattering on Argon (UAr) nuclei Ultimate goal of kt-scale global Ar dark matter observatory **DarkSide** 2023-2028 DS proto-1T DarkSide-20k 2020 +ARGO Optical & EM barrie nVeto Global Argon Dark Matter Collaboration DS 300 t proto-0 2019-20 DarkSide-50 50 tonnes (40 t fiducial) 1 tonne 50 kg 10⁻¹ WIMP mass [TeV/c²]

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LowMass:

Boulbv

Feasibility

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Feb

26th 2021

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Ultimate goal of kt-scale global Ar dark matter observatory

DarkSide 2023—2028

DarkSide-50 demonstrated access to low mass DM region possible with just ionisation signal:



RGC

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What is DarkSide-LowMass?

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Dedicated tonne-scale TPC with 'S2' signal from electroluminescence signal from ionisation electrons from DM-nucleon scatter

- Instrumented with large-area cryogenic high-efficiency ultra-low radioactivity SiPMs
- Enhanced sensitivity to low mass DM; probes neutrino floor



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First phase: Ultrapure UAr (1 µBq/kg) and SiPMs (1 mBq/PDM) building on STFC-funded UK R&D **Potential second phase:** doped LAr (Xe, allene, He) for reach and extra sensitivity

DarkSide-LowMass critically relies on:

- Reduction of Ar radioactivity to reach I μBq/kg (with UAr and Aria distillation column)
- SiPM radioactivity reduction to 1 mBq/PDM (x20 reduction on current generation)
- An Outer Detector to veto single neutron scatters (efficient as σ[n]>10²⁴ × σ[DM])

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Reaching DarkSide-LowMass with SiPM radioactivity reductions

Move from PMTs→SiPMs

Staged Si detector integration improvements

Programme of development STFC funded in the UK from 2021



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Direct detection in Silicon with DarkSide-LowMass

Low-radioactivity DarkSide-LowMass PDMs as a DM-Si target at Boulby?

- Target searches beyond WIMPs at keV—GeV scale (nuclear or electron recoils)
- Highly sensitive: background-free, I kg/yr of exposure (~400 PDMs) gives world-leading sensitivity
- Dependent on PDM radioactivity reductions by up to an order of magnitude



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Getting to DarkSide-LowMass: neutron veto

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WATCHMAN at Boulby:

Use detector in 2026+ as 6000t Gd-doped water instrumented neutron veto (and shield against external radioactivity) [same setup as used for DarkSide-50]



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Use detector in 2026+ as 6000t Gd-doped water instrumented neutron veto (and shield against external radioactivity) [same setup as used for DarkSide-50]

- DarkSide-LM TPC cylinder Im in radius and I.5 m tall Significant distance between TPC and veto walls improve shielding against untagged muons creating cosmogenic activation.
- Could be deployed through central top hatch planned for WATCHMAN
- Synergies with WATCHMAN programme 2026+ DarkSide-LM will have access to CEvNS neutrino floor. Links to non-proliferation programme.



DarkSide-LowMass requirements at Boulby

Location:

Needs to be co-located with AIT-WATCHMAN (!)

Depth:

With neutron veto, Ikm depth sufficient for control of external bkg

Clean room:

(~4m x 3m) with Radon abatement at 100 mBq/m³ level to assemble detector

Power:

Requirements for electronics ~0.2 kW; cryogenic system needs will need to be calculated

Other needs:

- Cryogenic argon vent line to handle catastrophic contact between LAr and (room temperature) liquid target of WATCHMAN
- Hook + need clearance of 3m above WATCHMAN to crane in detector

Operation of DarkSide-LowMass inside WATCHMAN at Boulby Laboratory ideal and would have world-leading discovery potential in a compelling and less-explored region of dark matter parameter space.

Use of the AIT facility beyond WATCHMAN to host DarkSide-LowMass is consistent with the foreseen timescale of the DarkSide international collaboration to field a dedicated low-mass instrument.

- Places UK in leading role for sensor production and as host laboratory
- Hosting and operation positions Boulby well for future related projects at scale
- Builds on new STFC-funded DarkSide project and aligned with UK DM strategic review priorities

