A Global Liquid Argon Dark Matter Search Program
Global Argon Dark Matter Collaboration

DS-20K (UAr, Dual Phase, 50 tons)

Argo (UAr, Dual Phase, 300 tons)

DS-50 (UAr, Dual-Phase, 50 kg)

ArDM (AAr, Double-Phase, 1 ton)

DEAP (AAr, Single-Phase, 3.3 tons)
Ultimate Goal

WIMP search down to the neutrino floor with no experimental background
Key technologies
Time Projection Chamber

DS-50  46.4 kg total mass

- Z position: S1/S2 time difference
- XY position: Fraction of light in each PMT in S2 pulse.
Key technologies
Liquid Argon

S1 → Scintillation signal
Prompt light Fraction: ER/NR discrimination

S2 → Ionization signal
S2/S1: ER/NR discrimination

ER → Electron Recoil
NR → Nuclear Recoil

DEAP 3600: astro-ph 1902.04048

ER background severely suppressed
Key technologies
Underground Argon

**AAr**: \(1\) [Bq/kg] of \(^{39}\text{Ar}\)

**UAr**: \(0.73\) [mBq/kg] of \(^{39}\text{Ar}\)

**URANIA** (Colorado, USA)
Extraction 250 kg/day at Kinder Morgan/Air Product plants.

**ARIA** (Seruci, Sardinia, Italy)
Distillation Column for final Argon purification (CO, CO\(_2\), H\(_2\)O, O\(_2\), CH\(_4\))

Also \(^{39}\text{Ar}\) further depletion for ARGO and DS-LowMass

**Transportation and Storage scheme**: avoid leakage and UAr activation

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V. Strickland
Key technologies
Photodetectors

Silicon PhotoMultipliers

- High Photon Detection Efficiency (>45% at 420 nm).
- Easily integrated into Tiles.
- Low Radioactive Background.

Required performance:
- DCR lower than 0.1 Hz/mm² at cryogenic temperatures
- Direct/Delayed Cross talk and Afterpulsing ~30%

PDM: 5x5 cm

Motherboard: 25x25 cm 25 PDMs
Key technologies
Material purity

Big effort in radioactive purity assays to assure the goal of 0.1 neutrons in 100 ton-year exposure.
Key technologies
Neutron background abatement

- **Material radio-purity**: Photo-Electronics front end and Acrylic Purity.
- **Fiducialization**:  50 ton (Active) 20 ton (Fiducial)
- **Outer Neutron Veto**
Key technologies
Proto Dunes Cryostat

Developed for DUNES. 8x8x8 m (inner dimensions)

Darkside+CERN Neutrino Platform partnership;
**DS-20K (2022-2027)**

**DS-20k TPC Dimensions**
- TPC Drift Length: 350 cm
- Octagonal Inscribed Circle Diameter: 355 cm
- Total LAr Mass: 51.1 t
- Active LAr Mass: 43.7 t
- Fiducial Cut Distance (vertical): 70 cm
- Fiducial Cut Distance (radial): 30 cm
- Fiducial LAr Mass: 20.2 t

**Nominal TPC Fields and Settings**
- Drift Field: 200 V/cm
- Extraction Field: 2.8 kV/cm
- Luminescence Field: 4.2 kV/cm
- Cathode Voltage: ~73.8 kV
- Extraction Grid Voltage: ~3.8 kV
- Anode Voltage: ground
- Gas Pocket Thickness: 7 mm
- Grid Wire Spacing: 3 mm
- Grid Optical Transparency: 97 %

**SIPM PDM**
- Number of PDM on TPC Top: 4140
- Number of PDM on TPC Bottom: 4140
- PDM Effective Area: $50 \times 50$ mm²

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TPC is an acrylic vessel 5 cm thick with field shaping rings coated.

Efficient use of UAr
Prototypes being constructed at CERN

Yi Wang

Proto-Proto

Testing
• The first two Motherboards.
• Acrylic bonding technique.
• Clevios coating.
• ESR reflectors

Optimization of S2 signal (Gas pocket)

Being commissioned at CERN this month
Proto 1 ton

Scaled down version of TPC

Testing sealed acrylic TPC

Validation of the final design

Q2 2020
The ReD project

If recombination depends on recoil direction in Argon -->
The neutrino floor is not a limitation anymore.
- $^7\text{Li}(p,n)^7\text{Be}$ tagging $^7\text{Be}$ with Silicon detector
- Neutron scatters elastically off $^{40}\text{Ar}$ at TPC
- Tagged by Liquid Scintillator detector with PSD capabilities
  - Array of LSci so recoils parallel/perpendicular to the electric field are tagged
On going experiment at LNS (Catania, Italy)

First results expected in 2020.
• Argon is sensitive to 2-10 GeV WIMPs if nuclear recoil detection threshold is $\leq 1$ keV$^{ne}$
• No ER/NR discrimination (detection based on spectral shape)
• Sensitivity depends on overall background level.

Scintillation signal threshold too high. Ionization signal needs to be used.

For Argon, $1$ keV$^{ne} \rightarrow 5-9$ electrons
The ionization signal in DS-50

1 electron $\rightarrow$ 23 PE (at the center of the TPC)

DS-50 is fully efficient for $N_e > 2$

Only events in TPC core are used (less background, a better single electron resolution)

For $N_e < 3$ background is mostly due to impurities.
The $N_e$ spectrum in DS-50

The first 100 days of the UAr run have $^{37}\text{Ar}$, very useful to calibrate the ER ionization yield at energies as low as 270 eV.
The expected $N_e$ spectrum for WIMPs
The corresponding cross section limits

DS-50 has excellent sensitivity in the 2-10 GeV mass range.

Not possible without **Underground Argon** (1400 lower $^{39}$Ar content than Atmospheric)

Very good prospects for DS-20K.
Conclusions

GADMC pursues a sensible search of WIMPs down to the neutrino floor with no experimental background.