Low Radioactivity Argon for Dark Matter and Rare Event Searches

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On behalf of the Global Argon Dark Matter Collaboration (GADMC)

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Toronto, ON, Canada
NEW SPEAKER. DARK MATTER TALK.
• DarkSide Program
• Current Experiments
• Future Projects & Experiments.
• Summary
• DarkSide Program.
• Global Argon Dark Matter Collaboration.
• 420 Researchers from 59 institutions and 14 countries.
• Current experiments: DS-50, DEAP, ArDM, MiniClean.
• Future experiments: DS-20K, ARGO.
• Labs: LNGS, SNOLAB, LSC & CERN.
Why Liquid Argon?

- Efficient Scintillator
- Unsurpassed discrimination
- Excellent Sensitivity
- Exceptional Radioactivity & Chemistry
- Relatively inexpensive

NR & EM

WIMP masses > 30 GeV$/$c$^2$ with single/two phase detection

Low radon backgrounds (160 nBq/kg of $^{222}$Rn, 2.6 nBq/kg of $^{220}$Rn in DEAP3600)
Current Experiments

**DEAP**
- Dark matter Experiment using Argon Pulse-shape discrimination.
- Single-phase liquid Argon (LAr) scintillation light detector, holding 3279 Kg at SNOLAB.
- Most sensitive WIMP masses > 70 GeV/c².

**ArDm**
- Argon Dark Matter target 850 Kg LAr.
- Only measured AAr, using a fiducial region of the inner 200 litres.
- Nowadays taking data in dual phase at LSC.
- Will be used as an active veto for future experiments (DArT/DarkSide-20k).

**MiniClean**
- Single phase detector utilize 500 kg of LAr.
- Fiducial mass region of 150 Kg
- Uses 92 sensitive photodetectors.
- Operating at SNOLAB since 2013.

**DarkSide-50**
- Dual-phase argon time projection chamber.
- Presently it is filled with of UAr.
- World’s most sensitive for WIMP masses in the range of (1.8 GeV/c² - 6.0 GeV/c²).
- $^{39}$Ar depletion factor 1400.
Spin-independent DM-nucleon cross section
90% C.L. exclusion limits / sensitivity curves
• Challenge: Argon radioisotopes; $^{39}$Ar (1 Bq/Kg), $^{42}$Ar (68µBq/Kg).

• Mantle gas has the lowest $^{39}$Ar production.

• Geological formation trap gasses underground.

• Argon source: CO$_2$ well in southwest Colorado (400 ppm Ar).

• DS-50: $^{39}$Ar = 0.73 mBq/Kg
  o 1400x reduction from AAr.
  o Low production
  o Suspected contamination with AAr.
Maximize the DM discovery potential with background free detectors

How?

Increment the production rate of UAr (Urania)
Further purification after extractions (Aria)
\(^{39}\text{Ar}\) reduction by the factor of 15,000 (DS-20K)
Reach beyond the sensitivity corresponding to the “neutrino floor” (ARGO)
• **Target:** extract and **purify** low-radioactivity UAr at a rate of 330 Kg/day with purity of better than 99.99%.
  - 50 tonne to fill DS-20K (LNGS 2022-2023).
  - 400 tonne to be stored at SNOLAB (ARGUS).
  - Future larger detector (ARGO – collecting argon 2022-2029).

• **Source:** Doe Canyon , Cortez, CO.

• **Urania feed:** ~ 95% CO₂ + few percent N₂ + 1% CH₄ + 430 ppm of UAr + traces of hydrocarbons.

• **Shipping/Transportation:** Phase 1 (DS-20K) & Phase 2 (ARGUS)

• **Operation:** October 2021.

• **Storage:** ARGUS – SNOLAB.
Gas Sampling & Analysis

Gas to RGA System
Feed from URANIA PLANT
Gas Container
To Cirrus 3-XD Heated Capillary Inlet, Pressure < 1000 Torr
Back to URANIA PLANT

The 16 channel multi-stream rotary valve & actuator at CU

Max Pressure 100 – 200 psi
Max Temp 75° - 200°C
Max 15 psi
• Goal: Purification for UAr to get detector grade Ar, free from N and other impurities.
• Two cycles are needed for separation of light and heavy components.
• Production in chemical mode (DS-20K): 1tonne/day.
• Commissioning scheduled by Q2 of 2020 in Sardinia, Italy.
- DArT is a small (~1 L) chamber that will measure the depletion of $^{39}\text{Ar}$ in UAr (URANIA/ARIA).
- Aiming 20% precision in a week for DF 1400 without lead shield. With lead shield 7%.
- The detector will be immersed in the LAr active volume of ArDM (active vito)
- Will be installed at the LSC and commissioned in the Q4 of 2019.
Next generation LAr detector for WIMP searches.
Consists of two detectors (inner & veto).
Operate with 50 tonne low radioactivity underground argon (UAr).
Membrane cryostat filled with ~700 tonnes of AAr.
Designed to reach an exposure of 100 tonne-year in background-free mode (less than 0.1 events of background).
Will be located at LNGS and commissioned by ~2023.
Spin-independent DM-nucleon cross section
90% C.L. exclusion limits / sensitivity curves

\[ \sigma = 9 \times 10^{-48} \text{ @ 1 TeV/c}^2, \quad \sigma = 9 \times 10^{-47} \text{ @ 10 TeV/c}^2 \]
• Target: Most sensitive WIMP search.
• Aims to reach beyond the sensitivity corresponding to the “neutrino floor” in DM searches
• Operate with \(~400\) tonne detector free of background UAr.
• Planning for 300 tonne (fiducial) for 3 ktonne-year free of background.
• Will be commissioned by \(~2029\).
• Currently exploring **detailed design**, including experience from progenitor experiments (both single-phase S1-only and dual-phase TPC).

• **Conceptual design** underway for other backgrounds (cosmogenic-related, neutrons, Cherenkov, etc.)

• Possibility of **intermediate-energy solar neutrino measurements**; **ktonne-year** exposure allows very sensitive measurements.

• Exploring the possibility of other physics measurements by **reconfiguring the detector** (e.g. addition of xenon or other gases) for sensitivity to other WIMP models or parameter space.
Spin-independent DM-nucleon cross section
90% C.L. exclusion limits / sensitivity curves

\[ \sigma = 9 \times 10^{-49} \, \text{at 1 TeV/c}^2, \quad \sigma = 9 \times 10^{-48} \, \text{at 10 TeV/c}^2 \]
• **GADMC** is aiming to maximize the DM discovery potential.
• **UAr** is promising technology for the future DM detectors.
• **DArT** is a small chamber will be installed in ArDM at LSC to measure the depletion of $^{39}$Ar in Q4 of 2019.
• **Aria** will do the chemical purification for UAr for $^{39}$Ar depletion in Sardinia in Q2 of 2020
• **Urania plant** will be ready for operation October 2021 and the first 50 tonne production July 2022
• **ARGUS** is the UAr storage facility will be located in SNOLAB.
• **DS-20K** is the next generation of LAr detector will be located at LNGS and commissioned by 2023.
• **ARGO** is the longer term objective of the GADMC aims to be the most sensitive WIMP search detector commissioned by ~ 2029, Preferred location SNOLAB.
Thank You!