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DARKSIDE MAIN FEATURES

- Dark Matter direct detection ➔ WIMP induced nuclear recoils
- Double phase argon Time Projection Chamber (TPC)
- Ultra low background
  - Underground laboratory ➔ LNGS
  - Low background materials
  - Ultra-pure Argon
- Active neutron tagging to reject neutron induced nuclear recoils and muon veto
- Powerful background rejection in Argon
  - Pulse Shape Discrimination (PSD)
  - Charge/Light ratio (S2/S1)
  - 3D position reconstruction
THE LIQUID ARGON CHOICE

**Pro**

- Relatively dense, cold and easy to purify
- High ionization and high electron mobility
- High scintillation yield (40 photons/keV)
- Very transparent
- Exceptional discrimination power, with respect to Xe:
  - Pulse shape discrimination (PSD)
  - Ratio charge/light

**Contra**

- Intrinsic $^{39}\text{Ar}$ radioactivity in atmospheric argon (AAr) is the primary background for argon-based detectors
- Less dense than Xe
Two scintillation time constants:

- singlet \( \sim 7 \text{ns} \)
- triplet \( \sim 1500 \text{ns} \)

Nuclear and electron recoils have different ratios of singlet and triplet states.

**Possible discrimination between NR and ER.**

**PSD parameter:**

\[ f_{90} = \frac{\text{light first 90ns}}{\text{total light}} \]

\[ f_{90} \approx 0.7 \implies \text{NR} \]
\[ f_{90} \approx 0.3 \implies \text{ER} \]
DARKSIDE MULTISTEP PROGRAM

DarkSide-10
2011-2013

DarkSide-50
2013-201X

DarkSide-20k
2020-202X
**Problem:** $^{39}\text{Ar}$ cosmogenically activated isotope emits $\beta$ ($\tau \sim 269$ yr and $Q \sim 565$ keV): AAr activity $\sim 1$ Bq/kg

$^{39}\text{Ar}$ limits the performance of the detector

**Solution:** the $^{39}\text{Ar}$ contamination in Argon extracted from the Earth’s mantle (UAr) is a factor $>1000$ lower than in AAr
HOW UNDERGROUND ARGON IN DS-50?

Extraction of a crude argon gas mixture from CO₂ Doe Canyon (Colorado) wells

Separation of Ar from He and N₂ at Fermilab

Shipping to LNGS by sea
QUALITY OF UNDERGROUND ARGON IN DS-50

The effective purification factor measured with respect to AAr:

\[(1.4 \pm 0.2) \times 10^3\]
Three nested detectors:

- Liquid Argon Time Projection Chamber (TPC): inner detector for WIMP search
- Liquid Scintillator Veto (LSV): active γ and neutron detector
- Water Tank (WT): active detector for muons

Operating @ LNGS in Hall C in the Borexino prototype structure
DOUBLE PHASE TPC

Double phase argon TPC

Two different scintillation signals

S1 light produced in liquid argon because of excitation and ionization

S2 electroluminescence light produced in gas argon by electrons escaped from recombination
TYPICAL TPC SIGNALS

Position reconstruction

➤ Time between S1 and S2 signals gives the vertical position of S1
➤ The distribution of the S2 signal on different PMTs allows x-y reconstruction
No events in the WIMP search region, with an exposure of 2,616±43 kg d (70.9 live days)

LIMIT EXTRACTED FROM UNDERGROUND ARGON DATA

Assuming standard cosmological parameter and considering spin-independent WIMP-nucleon cross section

Best limit from an Argon target
NEXT STEP: DARKSIDE-20K

Baseline requirements:

➤ Large scale liquid Argon Time Projection Chamber: 20 ton fiducial volume

➤ Radiopure construction materials

➤ Same veto system design as DarkSide-50

A KEY POINT

15 m² radiopure silicon photomultipliers (SiPMs)
HOW TO GET 30 TONS OF UNDERGROUND ARGON?

Urania
Expansion of argon extraction plant in Cortez to increase the extraction of UAr

Aria
Construction of a distillation column in Sardinia to purify UAr
Main advantages with respect to PMTs:

- More compact \(\rightarrow\) much lower radioactivity
- Readout pattern can be chosen at convenience
- Light yield increase

Custom SiPM development for cryogenic temperature by FBK and industrial cooperation for massive production in Abruzzo
FUTURE EXPECTED SENSITIVITY
Thanks for your attention!